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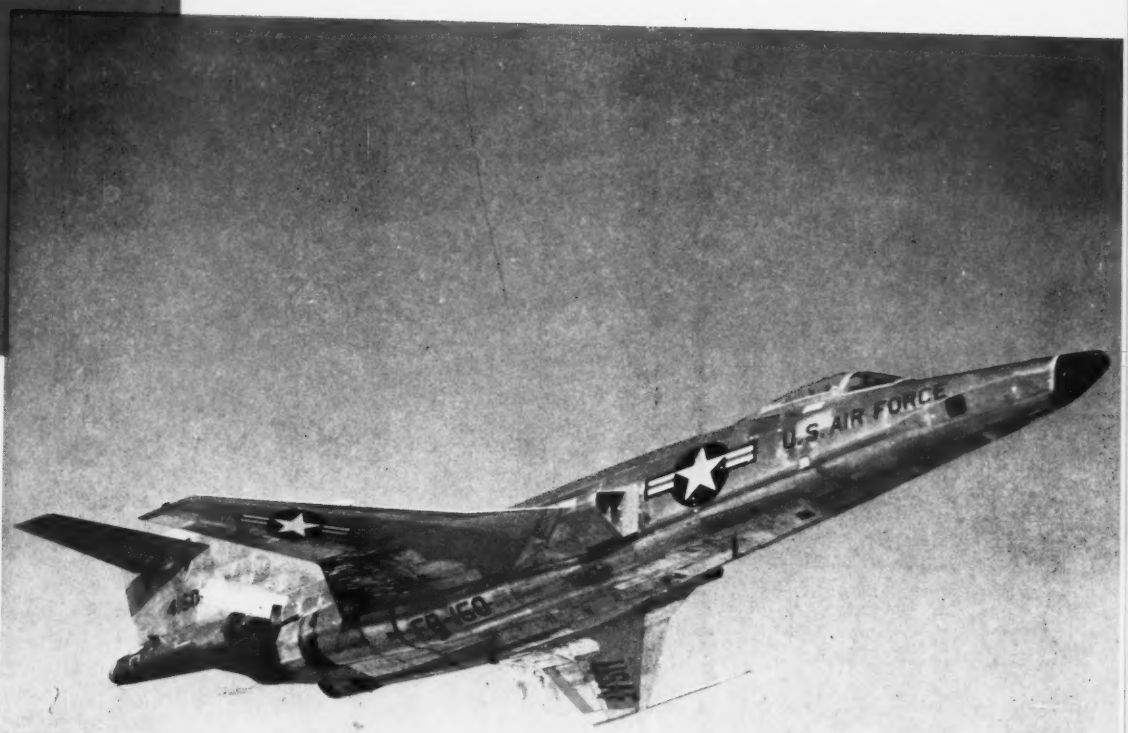

January, 1956

New Holley turboprop power control installed in Lockheed R7V-2

One hundred and six passengers or 36,000 pounds of cargo cruise at speeds up to 440-miles-per-hour in the Navy's new Lockheed R7V-2 turboprop Super Constellation. Four Pratt & Whitney Aircraft axial flow T-34 propeller turbine engines develop a total of 22,000 horsepower for take-off. Each of the four is automatically controlled by a new Holley gas turbine power control.

High performance turboprop engines like the T-34 demand extreme accuracy in fuel metering to maintain their high performance ratings and at the same time control operation within satisfactory limits. Through a system of accurately measuring four separate senses, the Holley control automatically meters corrected fuel flows to the engine in accordance with the engine operating requirements.

The Holley gas turbine control is the result of intensive research and development to provide a light weight, compact means of accurately metering fuel consistent with engine requirements.

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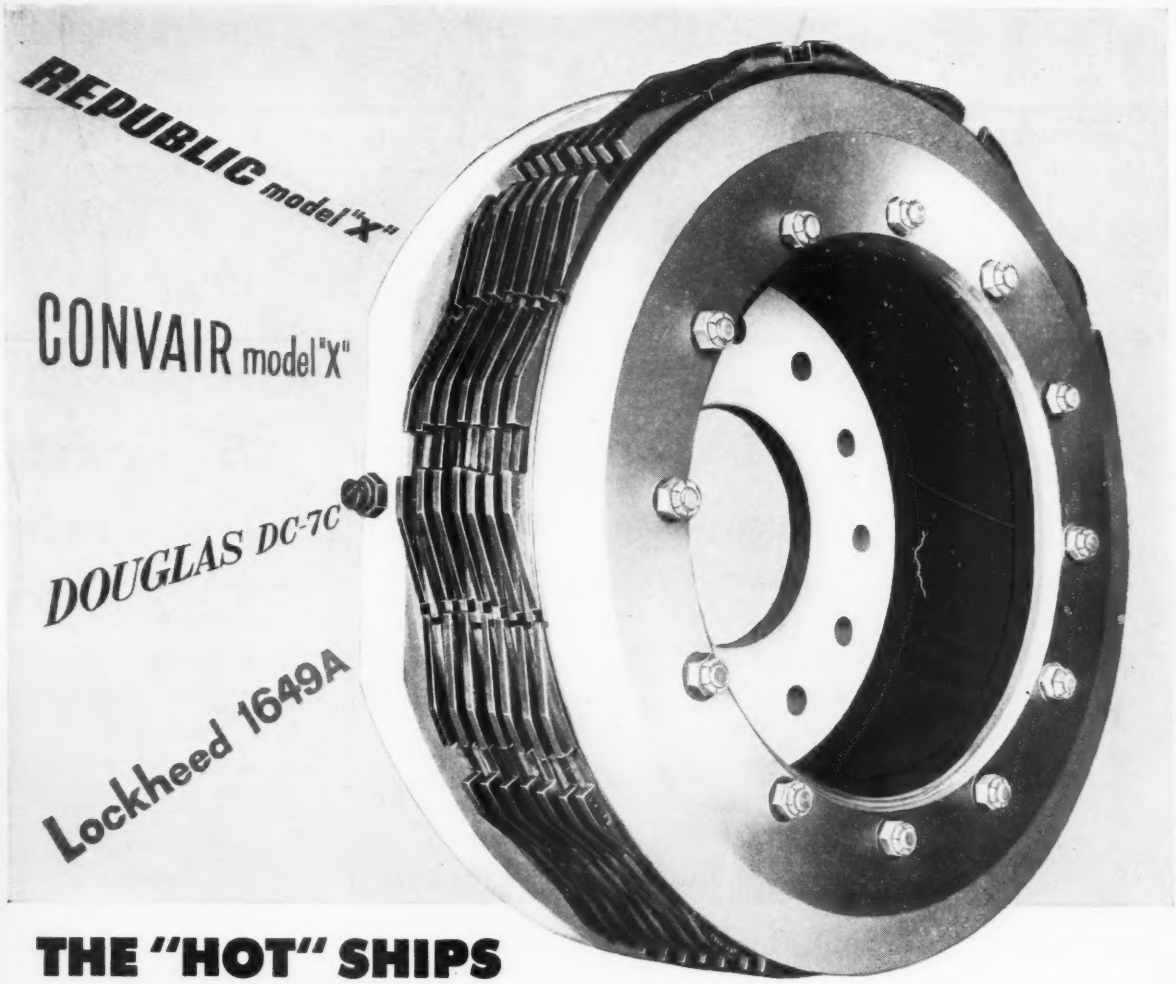

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are choosing the super-brake with the built-in "heat sink"

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It comes as no surprise that many of tomorrow's big and fast-flying aircraft are selecting the brake which gives up to *50% increase in absorption of kinetic energy per pound of brake.*

And so it is with the new Douglas DC-7C, Lockheed's Model 1649A and several new military planes on which model numbers have not been released.

Each of these aircraft specifies the new Goodyear Tri-Metallic Brake—the brake in which *the lining,* as well as its mating member and the brake structure itself, acts as a highly efficient "heat sink."

This increased heat absorption capacity per pound of brake is due to the fact that Goodyear has been able to combine the famed disc-brake efficiency with a new metallic lining material *—a non-insulating lining which operates at temperatures up to 70% higher than other designs of this type!*

The simplicity of design of the Goodyear Tri-Metallic Brake gives a spectacular reduction in number of parts—over 200 parts less than in other brakes of comparable capacity. This means greatly reduced inventory and maintenance man-hours.

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Aeronautical Engineering Review: United States and possessions, 1 year, $3.00; single copies, $0.50. Foreign countries including Canada (American Currency Rates), 1 year, $3.50; single copies, $0.50.

Entered as second-class matter at the Post Office, Easton, Pa., April 29, 1942. Acceptance for mailing at a Special Rate of Postage as provided for in the Act of August 24, 1912.

Publication Office: 20th & Northampton Streets, Easton, Pa.

Editorial Office: 2 East 64th Street, New York 21, N.Y. Notices of change of address should be sent to the Institute at least 30 days prior to actual change of address.

Statements and opinions expressed in the Aeronautical Engineering Review are to be understood as individual expressions and not those of the Institute.

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Aeronautical Engineering Review

Vol. 15—No. 1 January, 1956

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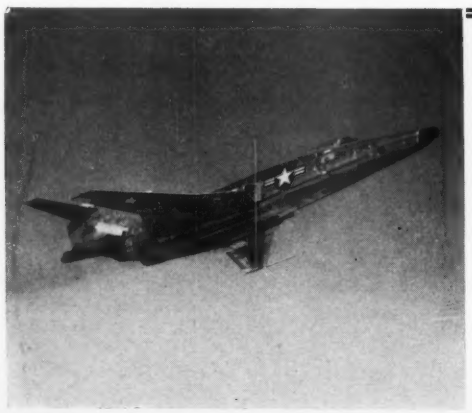

Cover—The first RF-101A, photo-reconnaissance version of the Voodoo, has been delivered to the Air Force by McDonnell Aircraft Corporation. The supersonic plane, whose twin jet engines develop 20,000 lbs. thrust, is equipped for in-flight refueling. A view finder permits the pilot to see the terrain below and ahead. He controls the cameras, which operate automatically. The dark area on the nose is an optical window, heated electrically to prevent fogging and frosting.

Published Monthly by the

Institute of the Aeronautical Sciences, Inc.

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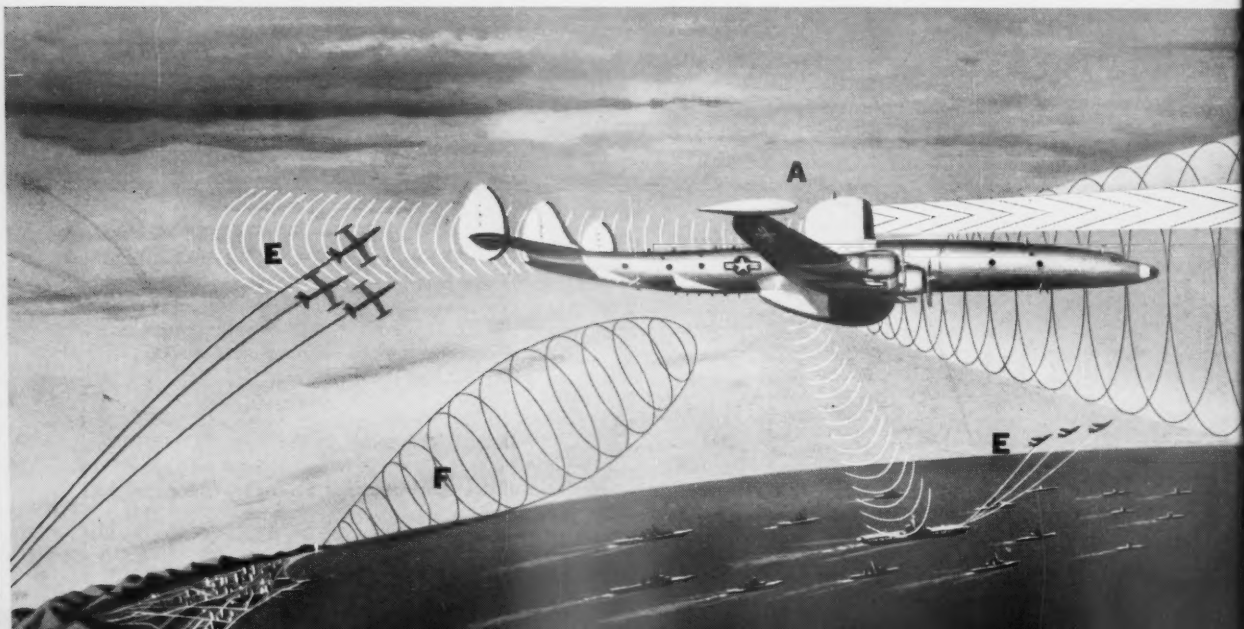
BELOW—A WEAPONS SYSTEM IN ACTION. An electronics-laden Super Constellation early-warning plane (**A**), patrolling our outermost defense perimeter hundreds of miles from our shores and borders, from its high altitude can "see" beyond the horizon and detect both high-flying and low-flying enemy aircraft (**B**). Using its powerful search radar (**C**) and height-finder radar beam (**D**) to pinpoint position of invaders, the patrol plane alerts our interceptors (**E**), which swarm aloft and are radar-guided through fog or darkness to intercept



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I.A.S. News Notes

January 1956

GLENN L. MARTIN, an Honorary Fellow, Founder Member, and Benefactor of the IAS, died in Baltimore on December 4 at the age of 69. Winner of the Collier Trophy, the Guggenheim Medal, and many other honors, he served as President of the Institute in 1936. He delivered the 1953 Wright Brothers Lecture marking the fiftieth anniversary of powered flight. In 1954, Mr. Martin established and endowed the Minta Martin Aeronautical Student Fund, which is administered by the Institute to encourage aeronautical engineering education. Income from the Fund provides for regional student conferences, lectures, publication of booklets, and distribution of films and other scientific information, all in relation to the advancement of the science of aeronautics. When funds were being raised to purchase the IAS Headquarters Building in New York, The Glenn L. Martin Company made a substantial contribution.

A HANDBOOK OF SOURCES OF AERONAUTICAL INFORMATION, which is being edited for the AGARD-NATO Documentation Committee by Cyril W. Cleverdon, Librarian, College of Aeronautics, Cranfield, England, is now entering the final stages of compilation. The Handbook is intended to list all agencies and organizations issuing unclassified aeronautical documents, and to give information concerning their various report series. Questionnaires were distributed last year. Those in the United States who wish to have their document series included should write to John J. Glennon, Librarian, IAS, who has been named Assistant Editor of the Handbook.

WALTER S. DIEHL says he is not participating in development of the Frye transport plane, as reported in the November Review.

NATIONAL MEETINGS CALENDAR

Jan. 23-26 Twenty-Fourth Annual Meeting, Sheraton-Astor Hotel, New York.
Jan. 23 Honors Night Dinner, Sheraton-Astor Hotel, New York.
Mar. 9 Flight Propulsion Meeting (Confidential), Hotel Carter, Cleveland.
June 18-21 Summer Meeting, IAS Building, Los Angeles.
Aug. 15-17 National Turbine-Powered Air Transportation Meeting, IAS Building, San Diego, California.

JOINT MEETINGS CALENDAR

Mar. 14-16 ASME-IAS-ARS Air Cargo and Thermal Barrier Sessions, Hotel Statler, Los Angeles.
May 14-16 National Conference on Aeronautical Electronics, Biltmore Hotel, Dayton, Ohio. Co-sponsored with IRE.
June 21-23 Heat Transfer and Fluid Mechanics Institute, Stanford University, Stanford, California.
Aug. 20-21 National Telemetering Conference, Biltmore Hotel, Los Angeles. Co-sponsored with AIEE, IRE, and ISA.

* * * * * *

I.A.S. News Notes (con't.)

SECTION MEETINGS CALENDAR

Jan. 4 Philadelphia Section: Joint Meeting with SAE at Philadelphia International Airport. Reception 6:30 p.m., Dinner 7 p.m. (Skyview Dining Room), Meeting 8 p.m. "The Economics of Large Aircraft" by Grover Loening, Aviation Consultant.

Jan. 5 Atlanta Section: Officers Club, Naval Air Station, Chamblee, Ga. Reception 6:30 p.m., Dinner 7 p.m. "Operational Experience with the Vickers Viscount" by J. B. Franklin, Vice-President for Operations and Maintenance, Capital Airlines.

Jan. 10 Los Angeles Section: Specialist Meeting at IAS Building, 8 p.m. "Transient Aerodynamic Properties of Wings: Review and Suggested Electrical Representations for Analog Computers" by B. Mazelsky and Robert O'Connell, Lockheed Aircraft Corporation.

Jan. 10 Tulsa Section: Danner's Cafeteria. Dinner 6:30 p.m., Meeting 7:30 p.m. "The Cessna-Seibel Helicopter" by Charles M. Seibel, Chief Engineer, Helicopter Division, The Cessna Aircraft Company.

Jan. 10 Washington Section: Occidental Restaurant. Reception 6 p.m., Dinner 6:45 p.m., Meeting 8 p.m. "Keeping Ahead of the Future" by Maxwell B. Bassett, The Glenn L. Martin Company.

Jan. 11 Chicago Section: Trans World Airlines Hangar. Dinner 6:30 p.m., Meeting 7:30 p.m. "Airline Transport Design" by R.W. Rummel, TWA.

Jan. 11 Los Angeles Section: IAS Building. Reception 6 p.m., Dinner 7 p.m., Meeting 8 p.m. "Flight Refueling -- Then and Now" by Ira C. Eaker, Elwood R. Quesada, and William Eubank, Jr.

Jan. 11 Niagara Frontier Section: Cornell Aeronautical Laboratory. Dinner 7 p.m., Meeting 8 p.m. "What Price Speed: Airplanes vs. Ships vs. Submarines" by Kenneth S. M. Davidson, Director, Experimental Towing Tank, Stevens Institute of Technology.

Jan. 12 San Francisco Section: Ramor Oaks Restaurant, Atherton, Calif. Reception 6:30 p.m., Dinner 7 p.m., Meeting 8 p.m. Talk on Activities of General Dynamics Corp., by L. B. Richardson, Senior V-P.

Jan. 13 Hampton Roads Section: Vic Zodda's Restaurant, Warwick, Va. Dinner 6:30 p.m. "The Origin of Turbulence in Fluid Motion" by Hugh L. Dryden, Director, NACA.

Jan. 18 Seattle Section: Boeing Engineers Theater. "Stress Analysis of a High-Speed Transport Wing" (a play) by Boeing Stress Unit.

Jan. 19 Baltimore Section: Maryland Hall (Room 101), The Johns Hopkins University, 8:30 p.m. "Helicopter Transportation within Metropolitan Areas" by Glen B. Eastburn, Asst. to President, New York Airways.

Jan. 19 Dayton Section: Levitt's Manor, 6:30 p.m. "Parachute Types and Systems" by Helmut G. Heinrich.

Jan. 24 Los Angeles Section: Specialist Meeting at IAS Building, 8 p.m. "Accessory Drive Turbines for Aircraft and Missiles" by O. E. Balje, Hydro-Aire, Inc.

Jan. 30 Los Angeles Section: Field Trip to the Packard-Bell Radio and Television Plant in the Los Angeles Area, 2 p.m.

Feb. 1 Philadelphia Section: "Guided Missile Engineering" by R. E. Gibson, Director, Applied Physics Lab., The Johns Hopkins University.

* * * *

IAS News

A Record of People and Events of Interest to Institute Members

E. R. Sharp Elected President for 1956

Council Also Chooses Four Vice-Presidents and Treasurer Who Will Be Installed at Annual Meeting

EDWARD R. SHARP, Director of Lewis Flight Propulsion Laboratory, NACA, has been elected President of the Institute of the Aeronautical Sciences for 1956. He will take office at the Honors Night Dinner in New York January 23 when Robert E. Gross, who has guided the IAS as President during the past year, will introduce him and turn over the gavel.

Chosen by the IAS Council to succeed Mr. Gross, who is President and Board Chairman of Lockheed Aircraft Corporation, Dr. Sharp will be the Institute's twenty-fourth President. He has been a member of the Council 4 years and is currently a Vice-President.

▸ **Other New Officers**—Following a meeting in Dayton, Ohio, the Council also announced the election of four Vice-Presidents and the Treasurer for 1956. The new Vice-Presidents are:

William B. Bergen, Executive Vice-President, The Glenn L. Martin Company, Baltimore. An Associate Fellow of the IAS, he has been a member of the Council for the past 3 years and is currently serving on the Editorial Advisory Committee of the AERONAUTICAL ENGINEERING REVIEW as a specialist in Aircraft Design, Structures, and Materials. He won the Lawrence Sperry Award in 1943.

Victor E. Carbonara, President of Kollsman Instrument Corporation, Elmhurst, Long Island, N.Y. A 1954 Council member, he is also an Associate Fellow and an editorial adviser to the REVIEW in the Instruments field.

Edgar Schmued, Vice-President in charge of Engineering, Northrop Aircraft, Inc., Hawthorne, Calif. He is a Fellow of the IAS and a member of the REVIEW'S Editorial Advisory Committee on Aircraft Design, Structures, and Materials.

Raymond C. Sebold, Vice-President of Engineering, Convair, A Division of General Dynamics Corporation, San Diego, Calif. Mr. Sebold, an Associate Fellow, is now a member of the Council.

The Council chose Sherman M. Fairchild, one of the Founders of the IAS and a member of its Advisory Committee, as Treasurer for 1956. He has served several previous terms as Treasurer, Vice-President, and Council member. A Fellow and Benefactor of the Institute, Mr. Fairchild is Board Chairman of Fairchild Camera and Instrument Corporation; President of Fairchild Recording Equipment Corporation and Sherman Fairchild and Associates, Inc.; and a Director of Fairchild Engine and Airplane Corporation, International Business Machines Corporation, and Pan American World Airways, Inc.

S. Paul Johnston was re-elected Director of the Institute, a position he has held since May, 1946. Robert R. Dexter was re-elected Secretary, and Joseph J. Maitan, Controller.

All the new officers except the President will assume their responsibilities at the Institute's Annual Business Meeting January 25, scheduled as part of the Annual Meeting to be held at the Sheraton-Astor Hotel, New York, January 23–26. They will be introduced at the Business Meeting, which all IAS members are invited to attend.

▸ **The President**—Edward Raymond Sharp, a Fellow of the IAS, will celebrate his thirty-fourth anniversary with NACA next month. He has been in charge of Lewis Laboratory, in Cleveland, since research on aircraft engines began there in 1942. Previously, he had been Administrative Officer of Langley Aeronautical Laboratory, Langley Field, Va.

Edward R. Sharp

Joining NACA as its fifty-fourth employee in 1922, Ray Sharp became Chief Clerk and Property Officer of Langley Laboratory in 1925 and Administrative Officer in 1936. As the NACA expanded and branched out from the parent laboratory, he was sent to Moffett Field, Calif., in 1940 as Administrative Officer of Ames Aeronautical Laboratory there.

A year later, he was recalled to Langley to make plans for the proposed engine research laboratory. Early in 1941, he was named Construction Administrator for this new facility and was transferred to Cleveland to direct its design and construction.

A native of Hampton, Va., Dr. Sharp holds a law degree from the College of William and Mary. He was admitted to the State of Virginia Bar in 1924. During the First World War he served in the Navy and retired from the Naval Reserve in 1941 with the rank of Lieutenant Commander.

Citing Ray Sharp for "leadership in the development and direction of one of the world's outstanding centers of aeronautical research in the new field of gas turbines, jet propulsion, and rockets," Case Institute of Technology conferred the honorary degree of Doctor of Science upon him in June, 1948.

CAI-IAS INT

(Upper left) Portion of audience at technical sessions in Convention Hall at Chateau Laurier Hotel. (Above) John Orr (center), chairman of CAI's Ottawa Branch, and B. J. Kaganov (right), morning session chairman, listen as Welman Shrader extends a welcome to the delegates on behalf of the IAS and its later-arriving staff officials. (Left) John H. Parkins, Director of the National Aeronautical Establishment, delivers the W. Rupert Turnbull Lecture.

The second International Meeting of the Canadian Aeronautical Society and the IAS proved as successful as the first one held a year ago. With Ottawa as the centrally located site, this year's conference drew a representative group of the aviation industry from all parts of Canada and the States. Approximately 400 people registered for the technical sessions, with the United States accounting for nearly one-third of the total.

Ten papers, five American and five Canadian, were presented during the two days of November 3 and 4. Under the chairmanship of B. J. Kaganov, Chief Structures Engineer for Canadair Limited, the following papers were read and discussed at the opening morning session:

Unique Structural Problems in Supersonic Aircraft Design—Fred P. Mitchell, Chief Stress Engineer, Avro Aircraft Limited.

Experiment and Theory in Investigating the Behavior of Structures at High Temperatures—Nicholas J. Hoff, Head, Department of Aeronautical Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn.

Optimum Structural Design of Wing Box Beams—Saul Bernstein, Group Leader, Stress Department, Canadair Limited.

Thursday afternoon was devoted to the presentation of the first W. Rupert Turnbull Lecture—established to perpetuate the memory of one of Canada's outstanding aviation pioneers and benefactors. The honor of presenting the first of these lectures went to John H. Parkin, Director of the National Aeronautical Establishment, who spoke on the work of W. Rupert Turnbull, 1870–1954.

Simultaneous sessions were held on Friday morning. I. A. Gray, Director of Engineering and Maintenance, Canadian Pacific Air Lines Limited, acted as chairman of the session on Aircraft Safety Design and Accidents. H. L. Eberts, President and General Manager, Fleet Manufacturing Limited, served as chairman for Materials and Processes. The three papers presented in each of the two sessions, respectively, were:

Significant Problems in Air Safety—Jerome Lederer, Managing Director, Flight Safety Foundation, Inc., and Director, Cornell-Guggenheim Aviation Safety Center.

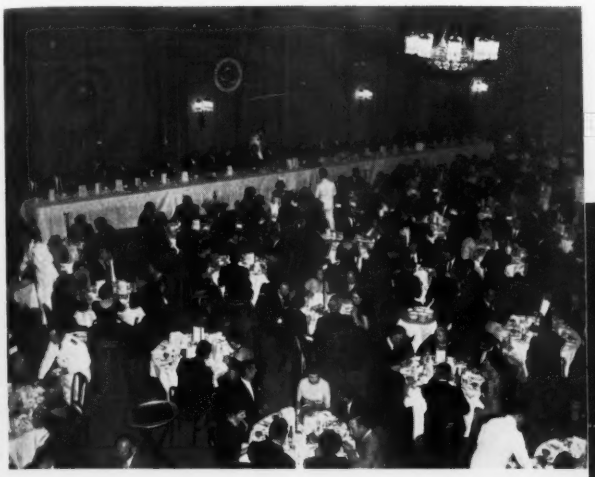
Aircraft Accident Investigation—Group Capt. Ralph C. Davis, Director of Flight Safety, RCAF Headquarters.

Recent Results of the NACA Crash-Fire Research with Jet Airplanes—I. Irving Pinkel, Associate Chief, Physics Division, Lewis Flight Propulsion Laboratory, NACA.

Aluminum Alloys for Elevated Temperature Service—E. H. Dix, Jr., Assistant Director of Research, Aluminum Company of America.

The Metal Bonding of Assemblies for the Canadair CL-28 Maritime Reconnaissance Airplane—Jason J. Waller, Chief Materials & Process Engineer, Canadair Limited.

AS INTERNATIONAL MEETING *at Ottawa*



(Above) The Ballroom of the Chateau Laurier during the International Meeting Dinner. *(Right)* R. D. Richmond, President of the Canadian Aeronautical Institute for 1955, serves as toastmaster. *(Below)* L. B. Richardson, a past president of the IAS, extends official thanks to Canada's Minister of Trade and Commerce, the Right Honourable C. D. Howe *(seated)*, for his interesting address as principal speaker at the International Meeting Dinner.

Materials and Fabrication Techniques for Structural Heat-Resistant Plastic Sandwiches—Norman E. Wahl, Head, Plastics Section, Materials Department, Cornell Aeronautical Laboratory, Inc.

A tour of the National Aeronautical Establishment laboratories was scheduled for Friday afternoon. In addition to an inspection of the various interesting facilities and laboratories of NAE, the group was given an opportunity to view the research model of the St. Lawrence Seaway. This is in operation at the Hydraulic and Ship Laboratory, Division of Mechanical Engineers, National Research Council.

A highlight of the meeting was the International Conference Dinner, held in the Ballroom of the Chateau Laurier on the evening of November 3. Over 700 persons—one of the largest banquets ever held in Ottawa—were on hand to hear the Right Honourable C. D. Howe, Minister of Trade and Commerce, deliver the principal address. He spoke on the development of aeronautics in Canada and traced some of the historical aspects and growth of the country's transportation systems.

R. D. Richmond, 1955 President of the Canadian Aeronautical Institute, and Chief Development Engineer, Canadair Limited, served as toastmaster and presided at the dinner. L. B. Richardson, a past president, and E. R. Sharp, president-elect, of the IAS, officially represented the Institute at the head table and made a few welcoming remarks.

This year's meeting elicited many favorable comments for those responsible for its organization and execution. Particularly deserving of credit are the officers and committee members of the CAI Ottawa Branch, under the chairmanship of John Orr, and the CAI's hard-working secretary, Charles Luttman, aided by his assistant, Mrs. Gladys Ross. The majority of papers presented at this meeting will be published in the CAI *Log* and the AERONAUTICAL ENGINEERING REVIEW.

IAS Compiling Catalog of 1,700 Technical Films

Information on 1,700 technical motion picture films in fields of interest to the Air Force is now available to industry, colleges, research organizations, Government agencies, and IAS members for use in research and for general information.

These motion pictures have been recorded in the Technical Film Catalog which is being compiled by the Institute of the Aeronautical Sciences under contract with the Air Research and Development Command of the Air Force. The Catalog office is located in the IAS Building at 3380 North Harbor Drive, San Diego 1, Calif.

This office does not maintain a film library and does not keep any films on hand. It functions solely as a clearing center for information. Inquirers will be told what subjects are available on film and where the desired films may be obtained. In most cases, the films are in the possession of the various companies, Government agencies, or military services that own them. The borrower will deal directly with the owner and make his own arrangements.

The Catalog is a card file, not a book. It has not been completed and is not suitable for mailing as a complete package.

Members and Corporate Members of the Institute may obtain information on specific subjects by writing or telephoning the Technical Film Catalog office in San Diego. Information on unclassified films will be furnished at once. Information on classified films will be furnished upon compliance with existing security regulations. The Catalog office will supply instructions on the method to be used in requesting information on the contents of classified films.

The Institute's San Diego Headquarters has received a facility clearance of "secret" from the Air Force, and all members of the Catalog staff are cleared for access to material classified through "secret." Work on the Catalog is performed in accordance with current regulations for safeguarding classified material.

The Catalog contains information relating to all phases of aviation and aeronautical research. Among the 1,700 films listed are many describing military, commercial, and private airplanes. Manufacturing processes and training films are well covered. Numerous other films are devoted to helicopters, convertiplanes, VTOL aircraft, missiles, rockets, components, materials, wind tunnels, and various methods of testing. In fact, the index contains more than 2,300 descriptive subjects.

Work on the Technical Film Catalog was begun in July, 1954. Sufficient information has been accumulated and indexed to prove of great value to those who make use of it. While the file was compiled primarily for use of the Air Force, its information is available to others, as stated above.

The personnel in charge of producing the Catalog realize that the surface has barely been scratched in the vast field of technical motion picture film available. They are continually trying to discover current films through personal contact and follow-up by telephone and letter.

Many companies have responded freely with descriptions of films they have produced, and others are beginning to recognize the great value of this information center in the saving of time and expense in research. All Corporate Members of the Institute should be cognizant of this activity and should make sure that all the technical motion pictures they have produced are listed. They also should advise their research and engineering staffs to use the Catalog as a source of information, just as they would request a library search for previously published material before undertaking any specific research.

Proprietary information is protected by the fact that the Catalog office does not have any films in its possession. Whether or not a particular film is released by one company for viewing by another is entirely a matter of negotiation between those concerned. The IAS does not arrange the loan and is not involved in the transaction.

The Catalog office will welcome inquiries from Members and will appreciate receiving any data relating to films that are not already listed and catalogued.

ROY W. ELLIOTT

Wright Brothers Memorial Trophy Goes to H. L. Dryden

Hugh L. Dryden, Director of the National Advisory Committee for Aeronautics, has been awarded the Wright Brothers Memorial Trophy for 1955. The trophy, which is administered by the National Aeronautic Association, has been awarded annually since 1948 "for significant public service of enduring value to aviation in the United States."

Dr. Dryden, an Honorary Fellow and Past President of the IAS, was cited for his "distinguished career entirely devoted to the public service, first with the Bureau of Standards from 1918 to 1947, and since then with the NACA." He was Associate Director of the Bureau of Standards.

"During his career with the Bureau of Standards," the citation continued, "he was engaged almost entirely on scientific aeronautical problems, largely those referred to said Bureau by the NACA and financed by NACA funds. By his pioneering work on the measurement of turbulence in wind tunnels and on the mechanics of flow within the boundary layer, he has made contributions of enduring value to aviation in the United States."

In addition to his NACA duties, Dr. Dryden serves the Government as a member of several scientific advisory committees.

R. T. Whitcomb of NACA Wins Collier Trophy

The Collier Trophy, representing "the greatest achievement in aviation in 1954," was awarded on December 17 to Richard T. Whitcomb, MIAS, a 34-year-old aeronautical research scientist of the National Advisory Committee for Aeronautics. He is Assistant Head of the 8-Foot Transonic Tunnel Section at Langley Aeronautical Laboratory, Langley Field, Va.

The Award Committee cited Whitcomb for his discovery and experimental verification (in a transonic wind tunnel) of the recently declassified "area rule" which made possible the development of the so-called coke-bottle or wasp-waist design for improving the performance of supersonic airplanes. The Committee called the area rule "a contribution to basic knowledge yielding significantly higher airplane speed and greater range with the same power." The citation said: "Whitcomb's area rule is a powerful, simple, and useful method of reducing greatly the sharp increase in wing drag heretofore associated with transonic flight. The use of Whitcomb's area rule in the design of supersonic aircraft greatly reduces wing drag and makes possible:

"The rapid acceleration of aircraft through the transonic speed range;

"The attainment of supersonic speed with less power than heretofore required and consequent increase in range; and

"The attainment of supersonic speed by aircraft which otherwise would be limited to subsonic speed."

The application of Whitcomb's discovery made the Grumman F11F-1 a supersonic plane and gave an extra 100 m.p.h. to the Convair F-102A, the citation said, adding that the area rule "is currently being used in the design of all transonic and supersonic aircraft in the United States."

The trophy was presented at the annual Wright Memorial Dinner of the National Aeronautic Association in Washington, D.C.

Wilbur Wright Elected to N.Y.U. Hall of Fame

The late Wilbur Wright was one of three noted men elected to the Hall of Fame for Great Americans at New York University in the 1955 balloting, announced November 1. A bronze bust of each winner will be placed alongside 83 others in the outdoor colonnade of the Hall of Fame, which is located on the Bronx campus of N.Y.U., overlooking the Harlem and Hudson Rivers.

With 86 votes, Wilbur Wright led General Thomas Jonathan "Stonewall" Jackson and George Westinghouse. His brother, Orville, who died in 1948, was not eligible for election because he has not been dead 25 years. The election takes place every 5 years.

NEWS OF MEMBERS

▸ **Leslie A. Bryan** (M), Director of the Institute of Aviation at University of Illinois, has been given the first University Aviation Association Award recognizing outstanding contributions to aviation education.

▸ **Capt. Martin B. Cahill** (M), of Northwest Airlines, Inc., has been appointed to the Technical Committee of the International Air Transport Association for a 2-year term.

▸ **Walter R. Dornberger** (AF), Missile Design Consultant to Bell Aircraft Corporation, received the G. Edward Pendray Award for literary contribution to jet propulsion at the Honors Night Dinner of the American Rocket Society. Dr. Dornberger, former Major General in the German Army and Commanding Officer at Peenemunde, recently published a book entitled *V-2* which recounts the development of this famous missile.

▸ **Harry F. Guggenheim** (HM), who has taken an active interest in rocket and jet propulsion since 1929, has been elected to Honorary Membership in the American Rocket Society. He supported the pioneering rocket experiments of Robert H. Goddard, and later established the Daniel and Florence Guggenheim Jet Propulsion Centers at Princeton University and California Institute of Technology. The award was presented at the Honors Night Dinner connected with the ARS Twenty-Fifth Anniversary Meeting.

▸ **Robert H. Jewett** (AF), Chief Engineer of the Pilotless Aircraft Division, Boeing Airplane Company, has been elected a Fellow of the American Rocket Society.

▸ **Curtis G. Talbot** (AF), of the General Electric Company, has been elected to the Board of Directors of the National Business Aircraft Association, Inc.

▸ **Juan T. Trippe** (AM), President of Pan American World Airways, Inc., was installed in October as President of the International Air Transport Association.

▸ **Edward G. Uhl** (M), Vice-President for Operations, The Glenn L. Martin Company, has been elected a Fellow of the American Rocket Society.

William G. Brombacher, FIAS, has been elected Secretary of the Instrument Society of America. He is a Consultant to the National Bureau of Standards, from which he retired after 33 years.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

John Boshar (M), formerly of Goodyear Aircraft Corporation, has joined Lockheed Aircraft Corporation, Marietta, Ga., as an Engineer in the Structures Department.

Major Gen. Albert Boyd, USAF (AF), former Commander of Wright Air Development Center, has been appointed to the new post of Deputy Commander for Weapon Systems at Headquarters of the Air Research and Development Command, Baltimore.

Alfred Africano, MIAS, formerly with Curtiss-Wright's Rocket Dept., has been named Head of the Power Plant Design Dept. of the Engineering Division—Missile Branch, Chrysler Corp., Detroit.

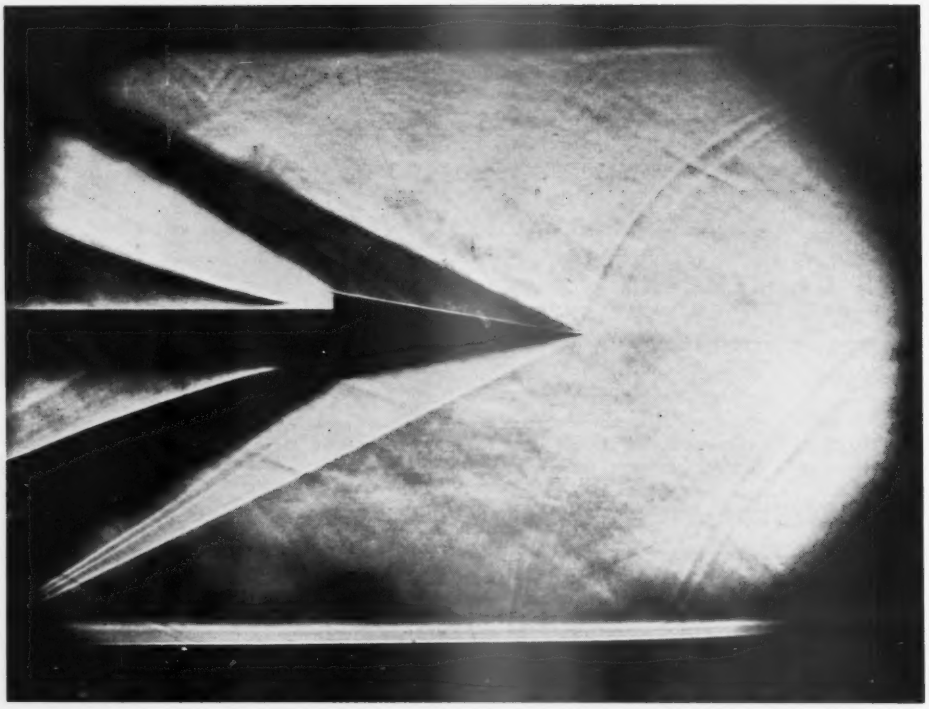
Gen. Benjamin W. Chidlaw, USAF (Ret.) (F), former Commander of the Air Defense Command and the Continental Air Defense Command, has been elected to the Board of Directors of the Sheffield Corporation, of Dayton, Ohio.

Ward F. Davidson (AF), Research Engineer of Consolidated Edison Company of New York, Inc., has retired after 33 years with the utility system. Recently, he has been planning for the company's entry into the nuclear power field. During World War II he was Deputy Executive Officer of the National Defense Research Committee and was awarded the Presidential Certificate of Merit for this work.

John F. Faulkner (M) heads the newly created aircraft-air frames section of the Cleveland Sales Development Division of Aluminum Company of America. He was formerly in the aircraft section of

(*Continued on page 58*)

William C. Keller, MIAS, has been named Manager of the new Customer Relations Dept. at Convair-San Diego. He was formerly in the Military Liaison Office of the Engineering Dept.



A New IAS Service

Just a year ago in these pages (Editorial, January, 1955), we described some of the ways in which the Institute was collaborating with various organizations on an international scale. At that time, the Fifth Conference with the Royal Aeronautical Society of Great Britain was in the final planning stages, and, after one joint meeting, our relationship with the newly formed Canadian Aeronautical Institute was firmly cemented.

It was pointed out also that we had been working closely with various committees and panels of AGARD—NATO's Advisory Group for Aeronautical Research and Development. In the field of technical documentation and library services in particular, the Institute has had a close and continuing interest.

One of the major areas in which we have made a considerable contribution in this connection has been in the indexing and abstracting departments of the REVIEW. For many years, this magazine has been a primary source of information for engineers and aeronautical scientists in locating reports, articles, books, and other publications in their particular fields of interest. We have considered it one of our primary missions to keep our readers up to date in the current literature.

In the past few years, however, the vast outpouring of periodical information has imposed an increasing strain on our capabilities. If only a few dozen important technical papers were received in our libraries monthly, it would be possible to read and analyze each one bit by bit, review it in detail, and provide an elaborate abstract. With over 3,000 separate items to look over every month, however, the most we have been able to do has been to list the title, the author, and the source and sometimes provide a brief descriptive statement of content. This, at least, offers some clues to REVIEW readers to enable them to evaluate the report in terms of their own needs.

It has long been our ambition to do something better than this, particularly for items of interest to readers all over the world. As Dr. Theodore von Karman said a year ago, "I believe an international abstracting service would secure a continuous and reliable flow of exchange of information at least in the unclassified field. . . . An international abstracting service would designate to the men interested in research and development what they should procure and read of the foreign literature. . . . It would be extremely valuable to friendly nations which have not the personnel or means for abstracting and reporting on everything that is going on in the world's literature."

Now, thanks to support furnished to us by the Air Force Office of Scientific Research of the Air Research and Development Command, we are actually launching

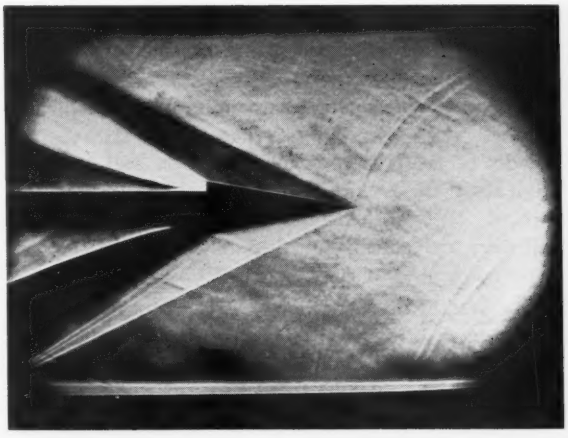
Editorial

such a service—the "International Aeronautical Abstracts." This will be an accelerated reviewing service covering world-wide scientific and technical literature. Readers will note a yellow page insert printed in offset which appears for the first time in this issue. This will be a regular feature of every issue. It will contain some 100–150 expanded abstracts monthly, covering technical reports and items received from all over the world which our reviewers consider to be of importance. By adopting the offset treatment and the insertion technique, we are able to get this information to REVIEW readers one or two months earlier than would have been possible before. The financial support derived from the contract with the AF-OSR-ARDC allows us to augment our staff and thus makes possible this expanded service.

It should be noted that all items that are abstracted in the "International Aeronautical Abstracts" yellow pages will also be indexed in a later issue of the regular "Aeronautical Reviews" section and therefore included in the annual AERONAUTICAL ENGINEERING INDEX.

As a result of this activity, the Institute is improving one of the important channels through which access may be had to technical reports on a world-wide basis. It is obvious that in most cases the actual documents must be in our hands for abstracting purposes. After they have passed through the hands of our reviewers, they will be placed in our library and will be available for inspection and for loan.

We would like to take this opportunity to express the thanks of the Institute to the U.S. Air Force for making this new service possible. This official action is not only a recognition of a need to be filled but also recognition of the Institute as a proper agency to undertake the work. We hope that our performance will justify the confidence they have placed in us. S.P.J.



Trends in Autopilot Developments

William P. Lear,* Lear, Incorporated

Components that might formerly have performed duplicate functions are eliminated or combined, and an optimum match between the man and the machine is sought. To illustrate this trend, aircraft body-axis rate stabilization, force steering, and remote gyro indication are traced from their wartime German origins to embodiment in the Lear L-10 automatic pilot.

(I) Introduction

A few years ago an automatic pilot was an aircraft accessory. It was installed, for convenience, often as an afterthought, in an aircraft built for and flown by a human. The pilot placed it in operation cautiously, without confidence that it would operate satisfactorily.

A few years hence some particularly daring pilot may even more timidly turn *off* his automatic flight-control system just in order to see what will happen.

In 1901 Wilbur Wright, addressing the Western Society of Engineers in Chicago, and with the ideas, successes, and failures particularly of the great German pioneer Otto Lilienthal in mind, said: "Men already know how to construct wings or aeroplanes, which when driven through the air at sufficient speed, will not only sustain the weight of the wings themselves, but also that of the engine, and of the engineer as well. Men also know how to build engines and screws of sufficient lightness and power to drive these planes at sustaining speed. . . . Inability to *balance* and *steer* still confronts students of the flying problem. . . . When this one feature has been worked out, the age of flying machines will have arrived, for all other difficulties are of minor importance."[1]

The Wright brothers, however, went on to work out the problem brilliantly. Their method of lateral and directional control by the human pilot, together with the previously invented elevator, has served well enough to stabilize and control almost every airplane up to the present time.

Today, however, students of the flying problem are once again confronted with a relative inability to balance and steer. This is because, since the Wright brothers' success, speed has been the main objective of aircraft design. As far as military aircraft are concerned, the faster an attacker can fly the more effective it is (while any opponent must fly still faster to be secure). The usefulness of a civil airplane is in fairly direct proportion to its speed.

We have come from the concern 50 years ago that the airplane would fly enough faster than headwinds to be useful, through the sonic barrier, to the verge of the thermal barrier. The Douglas Skyrocket, with test pilot Bill Bridgeman at the controls, has reached the almost incredible speed of 1,238 m.p.h. at an altitude of 79,494 ft.

In the past, the skill of the pilot has been able to conceal all but the most obvious deficiencies in handling qualities, while no amount of skill on the part of the pilot has ever concealed deficiencies in performance or structural integrity. For this reason, aircraft stability and control engineering were often subordinate and have only recently been emphasized by the emergence of stability and control difficulties of the most pressing nature. Modern trends dictated by the lift, drag, and thrust engineers have now aggravated stability and control problems to the point where they seem unsolvable without recourse to novel expedients.

Troubles come from any or all of the following conditions:

(1) High speed.

(2) High altitude.

(3) Small wings and high wing loadings.

(4) Unconventional wing shapes altering the relationships between aerodynamic parameters.

(5) Reduced wing aspect ratio and increased fuselage fineness ratio, together with redistribution of mass components.

(6) Wide variation in aerodynamic parameters in the transonic regime.

(7) Flexibility of the aircraft structure.

* Chairman of the Board.

Fig. 1 portrays graphically the influence of some of these features on the classical Dutch-roll motion. High altitude and high wing loading combine to give a high relative density, which has a destabilizing effect. Increased dihedral effect moves an airplane design toward instability. Similarly, reduced aspect ratio and increased fuselage fineness distribute the airplane's mass along the fuselage, which has a destabilizng effect. Aeroelastic effects introduce additional hard-to-stabilize oscillations.

All these features except the last are exemplified in the Douglas D-558-II Skyrocket. The Skyrocket, which has conventional, unboosted control surfaces, is illustrated in Fig. 2. This airplane, in fact, has poor lateral oscillation characteristics. The above rather abstract remarks on stability and control problems come alive in the following description by Bridgeman of his (previously mentioned) record-breaking flight.

"The ship began to roll violently as this low (0.25*g*) load factor was reached. Finally, the wings dipped as much as 75° on each side at a rate of 86° per sec. The sideslip angles reached a peak of 6.5°. As much as 65 lbs. of force was used on the ailerons in trying to combat this lateral action. Effectiveness was so low that it was deemed useless to exert any more force, plus the fact that it was extremely hard to remain out of phase with the roll and further aggravate it.

"As the data were reduced it was found that as much as 750 in.lbs. rudder hinge moment had been exerted as an aerodynamic load (against the locked rudder) by the lateral action, which is about the same as an 80-lb. force exerted by the pilot."[2]

Bridgeman's account certainly emphasizes the following characteristics of high-speed flight:

(1) The extremely large forces required to move the controls.

(2) Peculiar (often very nonlinear) feel characteristics and large variations in control surface effectiveness.

(3) Poor dynamic characteristics—damping is low or nonexistent, motions are extravagantly coupled, and the speed of aircraft response is incompatible with pilot reaction times.

A similar stability difficulty, inherent in the original geometric configuration, was the extreme yaw maneuver which caused the crash of George Welsh in the F-100 airplane.[3]

Refinement of aerodynamically balanced control surfaces and the search for a more favorable airplane geometry do not appear to be satisfactory expedients.

Fig. 3 illustrates the relatively small effect on the lateral oscillation of large changes in vertical tail size. The curves sloping down to the right are lines of constant time to damp to half amplitude. An increase of vertical tail size of 50 per cent reduces the time to damp by less than a third, and the period gets shorter so that from the pilot's viewpoint the net effect on dynamic stability is negligible. Furthermore, there is conflict between the requirements of stabilization and control if stabilization is achieved with fixed surfaces. A small amount of artificial damping could move the design completely off the graph to the right without increasing the size of the fixed surfaces.

Closed-loop controls are an attractive solution to airplane stability and control problems. Servomotors can supply the power to move the surfaces; feedback can linearize the feel characteristics and overcome variations in control-surface effectiveness; and finally suitable feedbacks can alter the dynamic characteristics. Fig. 4 illustrates, in a simple form, these features of automatic control.

The aircraft of the future will depend for successful flight on powered controls, artificial feel, artificial stability, and improved methods of sensing, indication, and control. These means will be assembled into an integrated flight-control system which will embody the functions of the attitude-stabilizing automatic pilot—but will be much more. Duplication of functions will be eliminated except where required for reliability, and the system will be tailored to the individual requirements (particularly the dynamics) of the air frame in which it is installed. Fig. 5 is intended to show some of the functions and components of a typical integrated flight-control system. It includes the air-data system, the master attitude system, and the power control and feel system. The integrated flight-control system will be as much a part of the airplane as the engine, and the

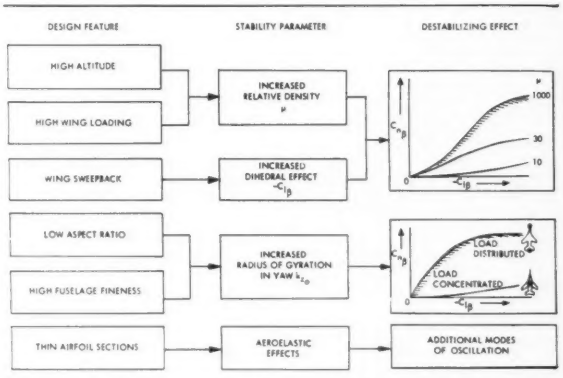


FIG. 1. The influence of modern design features on the Dutch-roll motion.

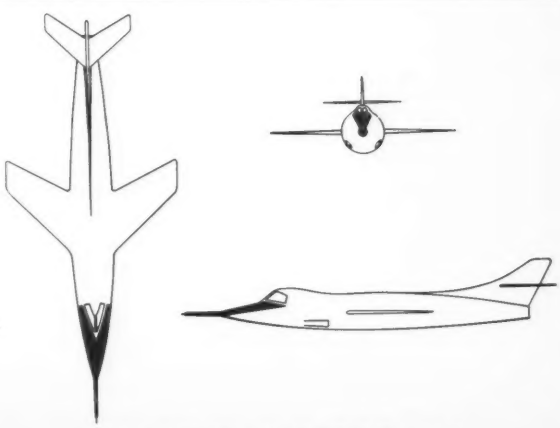


FIG. 2. The Douglas D-558-II Skyrocket.

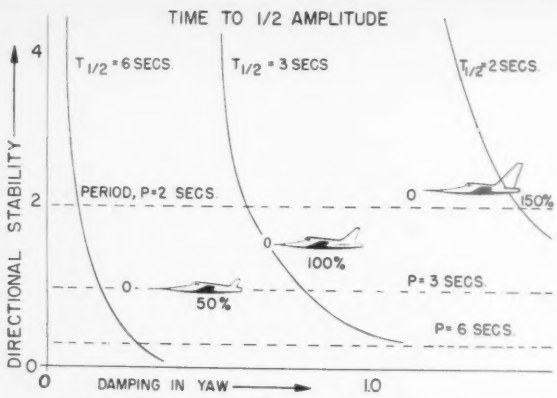


FIG. 3. Effects of tail size on the Dutch roll.

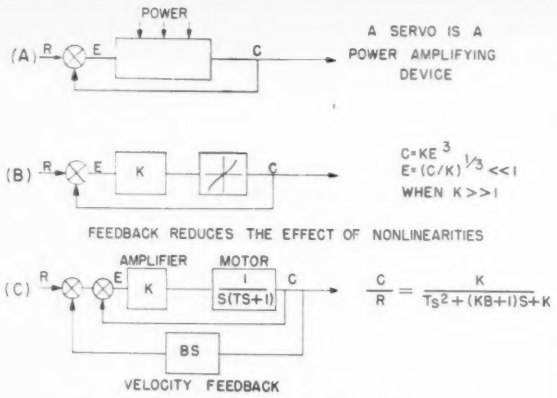


FIG. 4. Suitable feedbacks improve dynamics.

FIG. 5. Integrated flight-control system.

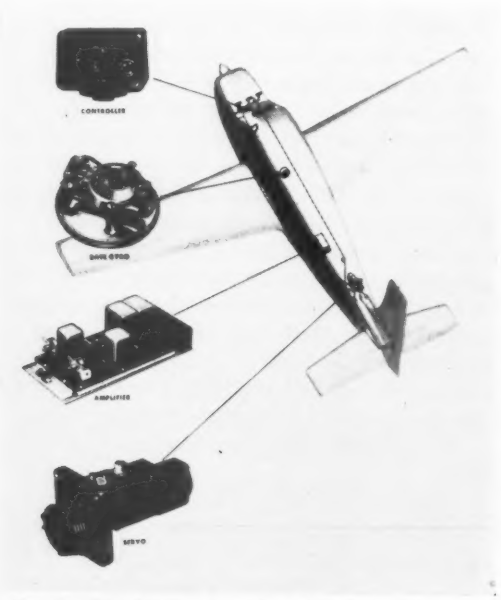


FIG. 6. The Arcon automatic-rudder control system.

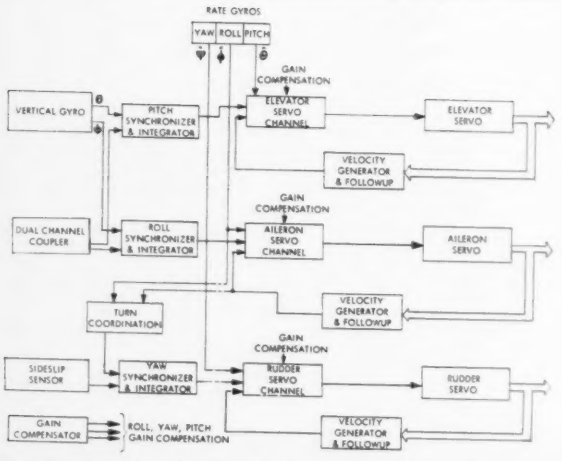


FIG. 7. Simplified functional block diagram of the Lear L-10 automatic pilot.

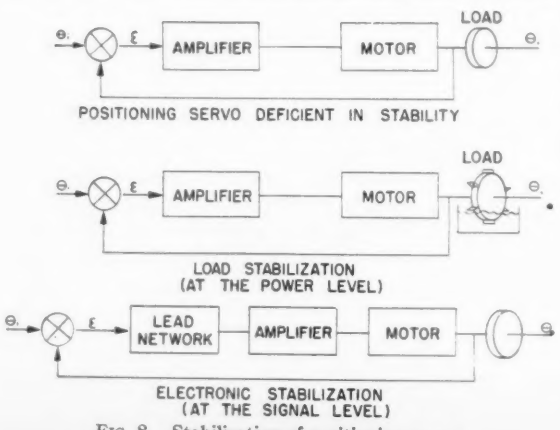


FIG. 8. Stabilization of positioning servo.

airplane will be no more capable of flying without it than without its power plant.

A complete discussion of trends in the development of integrated flight-control systems would overextend this paper. I have, therefore, chosen to expose in detail only three features of the Lear L-10 automatic pilot. Body-axis rate stabilization, force steering, and the remote indicating vertical gyro were originated in Germany. These three features, however, are perhaps typical of the modern flight-control systems in the United States and represent a considerable departure from American autopilot design practice as it existed 10 years ago.

(II) Artificial Stability or Body-Axis Rate Stabilization

Perhaps the first to recognize that gyroscopic stabilization and servocontrol would be absolutely required on modern aircraft, especially fighters, was Doetsch of the Deutsche Versuchsanstalt für Luftfahrtforschung. His ideas on the subject of artificial stability as a means to overcome stability deficiencies dictated by considerations of performance appear to date from as early as 1942. The special merit of automatic stabilization in addition to whatever aerodynamic stability may exist, with respect both to maintaining maneuverability and to avoiding an increased susceptibility to gust disturbances, was discovered and propounded by Doetsch. His convictions were probably based to a large extent on theoretical considerations, and certainly several notable German reports—including those by Pinsker[4] and Scharn[5]—indicated that satisfactory aerodynamic stabilization alone was becoming increasingly difficult.

In another connection, at the firm of Blohm and Voss, Vogt was putting artificial stability into practice. Here the problem was the maintenance of pitch attitude during water take-off. In 1943, for the BV 222 six-engined flying boat, Vogt employed a split elevator. One part was controlled by the human pilot, the other part by the gyroscopic pitch-attitude stabilizer. Any dissimilarity here between the artificial-stability equipment and the conventional attitude-stabilizing automatic pilot is perhaps difficult to see. Indeed Vogt's artificial stability was mechanized with Askania and, later, Patin automatic pilot components. The concept, however, of the stabilizer as an aid to the pilot in the manual flying of the aircraft differs from the conventional viewpoint.

Furthermore, starting in 1943, the automatic pilot manufacturers brought out the so-called single-axis automatic pilots. The reputations of Kronenberger and Moeller at Askania and of Klein and Dudenhausen at Siemens are associated with these developments. The firm of Patin also brought out a single-axis fighter autopilot.

These equipments were substantial aids to the manual flight of the aircraft, but they were not really automatic pilots. It is pertinent to note that one of the most pressing requirements for such a device was as an aid to instrument flying.

When yaw dampers were first introduced into American aircraft in 1947, they were viewed primarily as Dutch-roll damping augmenters, and it is only recently that their value to the less skilled instrument pilot in preventing spiral divergence has been fully appreciated. Today there is a large market for the Lear Arcon (an automatic-rudder-control device) in light personal and business aircraft (which have no need for Dutch-roll damping augmentation). Fig. 6 shows a typical Arcon installation. The compact package contains the gyro, servomotor, servoactuating clutches, printed circuit, magnetic servoamplifier, and an inverter for gyro motor and pickoff power. High producibility and the resulting low cost are prime requirements in the Arcon design.

In military aircraft there are not only yaw dampers but also pitch and roll dampers. Sometimes they exist independently, and sometimes they are part of a more elaborate autopilot system which has additional capabilities.

The L-10 automatic pilot, unlike its predecessors in the Lear automatic pilot line, provides roll, yaw, and pitch damping from rate-sensing gyroscopes. Fig. 7 is a block diagram of the L-10 automatic pilot. The rudder channel operates independently of the other two and can be employed completely separately as a damper and coordination control. This is a considerable departure from previous practice in three-axis automatic pilots where the rudder has been employed as a means for controlling heading.

The scheme for holding heading in the L-10 automatic pilot involves banking in order to make heading corrections. This is a much more efficient method of making even small corrections to the direction of the aircraft's track than skidding to the desired heading and allowing the sideforce due to sideslip to apply the centripetal acceleration which actually turns the airplane's velocity vector.

In manual flight, with damper operation, the action of the rudder in response to the lateral accelerometer provides an airplane with the much desired two-control characteristic. Even under automatic control with force steering this independence of the rudder channel avoids the need for pedal force sensors, unless there is a requirement for deliberately skidding the airplane.

Almost all of today's automatic pilots are built around inner body-axis, rate-stabilizing loops which augment with artificial stability the airplane's natural damping in pitch, roll, and yaw. This shift in emphasis from attitude angles with respect to the earth to the detection and control of body-axis rates in space marks the transition of the autopilot from an aid to navigation—that is, altitude, heading, speed—to the full status of a maneuvering aircraft artificial controller and stabilizer.

(III) Force Steering

Closely allied with damper development is the development of force steering. This revolutionary German concept combined the aerodynamicist's view of

stability and control with the view of the servomechanist and autopilot engineer and brought about the final resolution of the dilemma between aircraft stabilization and control. Unfortunately, the significance of this development was obscured by the confusion of events, and, since no written record has been discovered, the full story of the origin of stick steering for automatically controlled aircraft may never be known.

As far back as 1891 gyroscopically actuated servocontrols were proposed as a solution to the "balancing and steering" problems for aircraft.[6] A "stable airplane" with a three-axis, electric, automatic pilot was actually demonstrated in Paris in 1914. Such a stabilizer, however, like fixed surfaces, interfered with the human pilot's control of the airplane.

The ease with which a pilot can fly steadily in straight flight is a function of how well the airplane resists changes in its velocity vector, and the ease with which a pilot maneuvers is a function of the means available to him to alter the magnitude and direction of the velocity vector.

As far as the pilot is concerned, stabilization achieved either through an increase of the size of fixed surfaces or through gyroscopically actuated parallel servos interferes with his control of the aircraft's flight path. Stability and control are therefore widely held to be mutually contradictory, and indeed stability must be sacrificed for control and vice versa if one attempts to introduce the control at the power level. If, on the other hand, the stabilization is obtained by feedback principle and control and stability are mixed at the signal level, the contradiction disappears.

Fig. 8 illustrates the fact that control and stability are not necessarily incompatible, at least in servomechanism technology. The first servomechanism is deficient in dynamic stability. The damping may be improved at the output end, as is done in the second case. This is analogous to the provision of larger fixed surfaces on an aircraft. On the other hand, the damping may be introduced at the signal level, as is illustrated in the third case. This conserves control power and results in smaller system errors. Improved stability and control are accomplished simultaneously.

The knob type of flight controller was first introduced approximately 15 years ago in an attempt to mix stabilization and control signals in the automatic pilot. This device allowed the pilot to control the airplane-automatic pilot combination and achieved a measure of control with stability. A Lear flight controller is shown in Fig. 9. This unit, which was designed for the pitch and roll attitude control of fighter airplanes, is exceptionally economical of valuable cockpit space.

The flight controller, however, is not entirely satisfactory from a human point of view. It requires the pilot to fly in two completely different ways depending on whether the automatic stabilizer is in operation or not. How, after all, does the pilot expect to fly the airplane? What seems to him to be the most acceptable means of controlling the attitude and flight path? How can these characteristics be achieved? These questions have been the subject of a tremendous amount of flight research in many countries, and a great store of specific details has been accumulated. The essence, however, is that the pilot controls the airplane with forces applied to the stick. He expects that

(1) A force applied in the longitudinal direction will produce a proportional pitching rate.

(2) A force (preferably extremely light) applied in the lateral direction will rapidly produce a proportional rolling rate.

(3) A very small force or no force at all should be required on the rudder pedals for any coordinated maneuver.

The attempt to achieve satisfactory stick force per g, aileron characteristics, and directional stability has preponderantly occupied the attention of the stability and control aerodynamicists ever since these characteristics were identified as the most important handling qualities. An airplane with automatic pitch and roll damping and automatic rudder control for coordination and damping is ideally suited to the relatively facile achievement of these characteristics.

As an outgrowth of the damper developments, and based on the fortunate built-in torquer characteristic of the electric spring, there was developed in Germany in late 1944 and early 1945 a stick-force steering automatic pilot. This was the result of the combined efforts of the firms Askania and Siemens and of the Research Station for High Altitude Flight. Klein and Dudenhausen were directly associated with this work. The success of the project was due, in part, to the strong support of Siegfried Knemeyer in behalf of the government and also to the appreciation of the problem and the encouragement given for its solution by Vogt, Blume, and Heinkel in behalf of the air-frame companies. Before the war ended, three-axis force steering of an automatically controlled aircraft had been demonstrated in flight.

Today in the United States the electrical measurement of the force applied to the control stick or wheel, used as a body-axis rate command input to the airplane-automatic pilot combination, is becoming the standard method of achieving pilot control in automatic flight. Direct force sensing offers advantages with respect to handling qualities in all types of aircraft, including civil transports.

There is no limit to the potentialities of this technique as long as the pilot uses the now conventional cockpit controls. If, for example, a biased-off angle-of-attack signal is summed with the pitch rate and elevator stick force signals, the automatic pilot servo can be made to provide an extremely desirable stall warning feel. The use of the conventional controls for control of the airplane-automatic pilot combination permits the elimination of the automatic pilot flight controller from the cockpit, and cockpit simplification is much sought after. Furthermore, direct electrical sensing of pilot-applied force offers a means of overcoming the stability problem

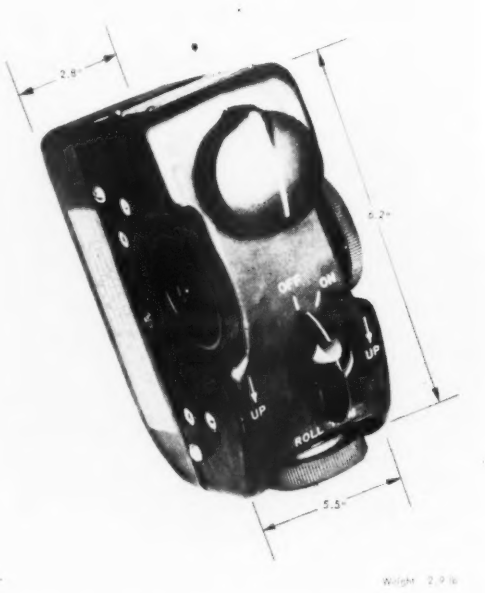


FIG. 9. Flight controller, Lear Model 996J-1.

FIG. 10. Experimental control stick with sensor.

FIG. 11. Wheel-force sensor.

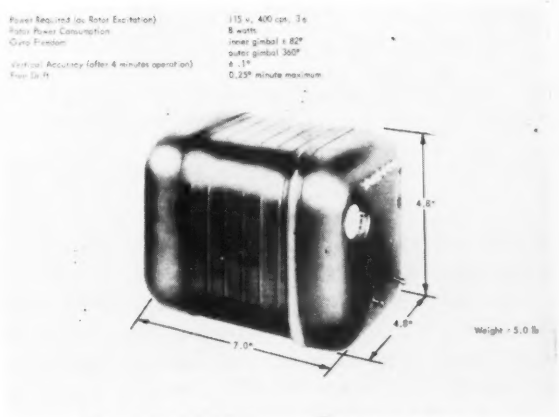


FIG. 12. Vertical gyro, Lear Model 2153A.

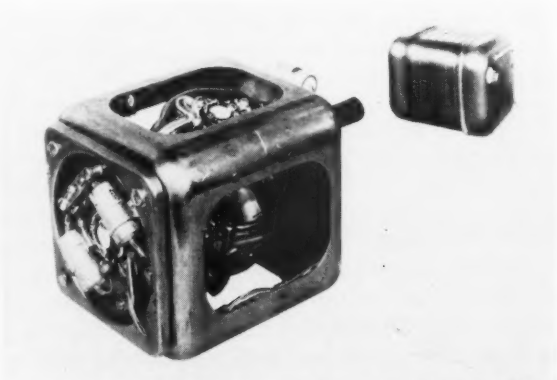


FIG. 13. Uncanned steel vertical gyro, Lear Model 2153A.

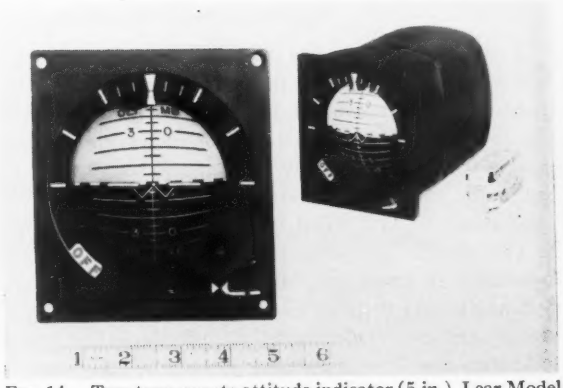


FIG. 14. Two-tone remote attitude indicator (5-in.), Lear Model 4005A (with integral lighting and amplifiers).

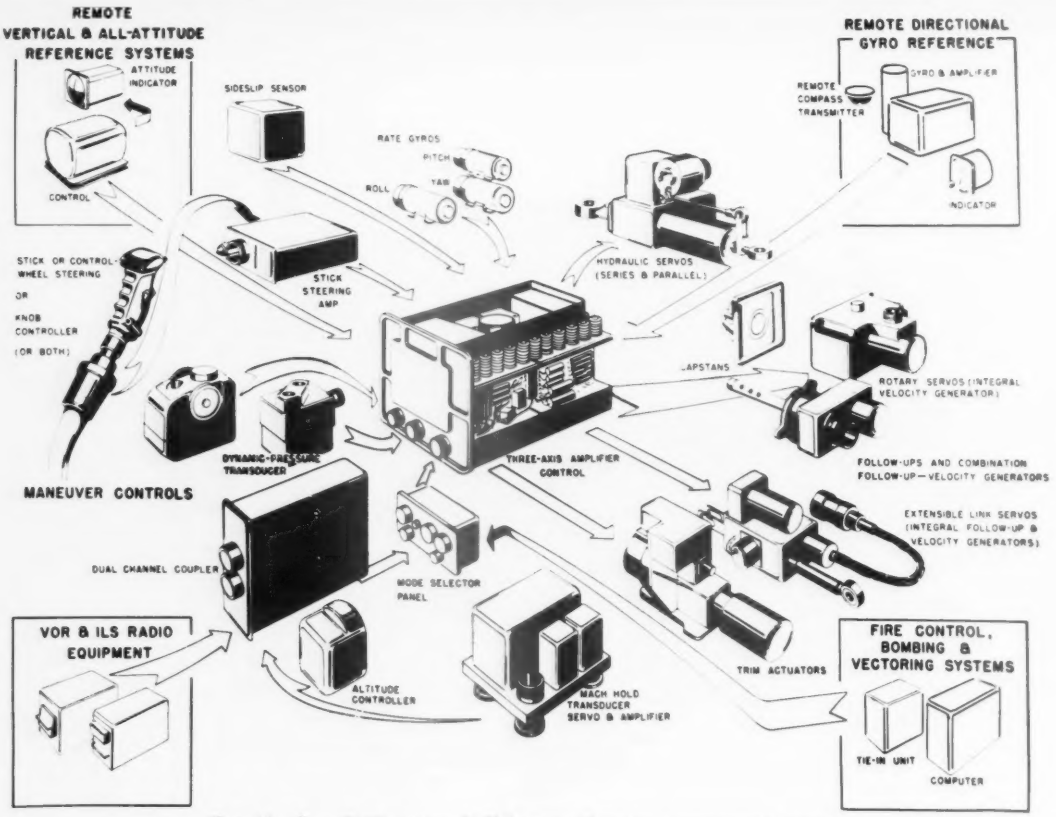


FIG. 15. Lear L-10 automatic flight-control system, components layout.

created by friction, preload, and backlash in hydraulic powered flight controls.

Figs. 10 and 11 show the stick and wheel force sensors which are optional features of the L-10 automatic pilot. The bulk of the sensing elements is attributable to the microsyn-type pickoffs which are required to match the characteristics required for inputs to transistor amplifiers. These force sensing units have had an enthusiastic reception among flying personnel.

(IV) Remote Vertical Gyro Indication

A third feature of the Lear L-10 automatic pilot which had its counterpart in wartime German developments is the common use by the automatic pilot and the panel instrument of a remote indicating vertical gyro. While some early pneumatic or hydraulic automatic pilots used a common gyro for automatic pilot reference and panel indication, the introduction of the electric and maneuvering autopilot led to a separation of functions. Before long it was not uncommon to find three or more vertical gyros in a single-seater airplane. One might be used for the panel indicator, the second for the automatic pilot, and a third for radar antenna stabilization. This represented an extremely undesirable redundancy.

Starting in 1943, Moeller of the firm of Askania developed a stable platform which was intended to provide angular error signals for all purposes in the airplane and was equipped with resolvers for transforming earth-axis information into airplane body-axis information. This was a great innovation and originated the whole field of stable platform engineering.

At about the same time Von Peteri of the Anschutz Company in Kiel developed the more modest Lotzentrale, which was a component of the Patin three-axis autopilot. This unit was designed to provide signals for at least the automatic pilot, the bombsight, and the panel indicator. A rudimentary vertical gyro indicator was developed in which the miniature symbolic airplane was moved with respect to the horizon by galvanometer elements.

Fig. 12 shows the latest Lear vertical gyroscope which is designed to provide electrical signals for the panel indicator and automatic pilot and to serve other purposes in the airplane. Fig. 13 shows the gyroscope with the hermetically sealed can removed. Construction of the unit is particularly interesting. The parts are almost entirely made of pressed steel. Since all the parts are of the same material, and all expand and contract the same amount with temperature, loads on the bearings and unbalances due to differential expansion are avoided. Therefore, this Lear gyroscope has exceptionally high performance and accuracy and is produced economically.

Fig. 14 illustrates the vertical gyro indicator which is the repeater for the steel vertical gyro. The "two-tone" indicator is sensed in the conventional manner for a gyro horizon, but it is capable of displaying clearly any aircraft attitude. Lighting for night flight is built into the indicator, and the transistor amplifiers for the sphere servodrives are also built into the case. This allows several repeater indicators to be driven from the same source without compromising performance.

This vertical gyro indicator is most modern, but the next few years will bring about the development of even more advanced displays to meet the requirements of high-speed, all-attitude flight control.

(V) Conclusion

Predictions are dangerous, but the discussion of trends in autopilot development involves a prognostication of autopilot characteristics. Extrapolation from known data is accepted practice in engineering, and therefore the characteristics of a completely modern autopilot may furnish a clue to future designs.

Fig. 15 illustrates the components of the L-10 automatic pilot. Prominent positions in the system are occupied by the rate gyros for artificial damping of the air frame, the force stick steering, and the remote vertical reference system. The next Lear automatic pilot will incorporate even more integration of the various gyroscopic and air data reference systems, of the force-steering and aircraft feel systems, and of the aircraft surface actuators together with the autopilot servos.

Trends in aircraft design will continue to compromise stability characteristics. The aircraft will become almost unflyable without automatic controls. Failure of the automatic control will be an emergency condition similar to engine failure. Therefore, in a few years, a pilot may dare to turn off his automatic flight control in order to see what will happen and whether he can cope with it—as he now practices power-off approaches and landings.

Since the aircraft will become completely dependent on the integrated automatic flight-control system, great advances in the reliability of equipment and improvements in design for high-volume production and low cost are requirements that will be met.

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Load distribution, wing shape, internal pressures, and landing gear design—as analyzed by the structures engineer in terms of weight.

Unique Structural Problems in Supersonic Aircraft Design

F. P. Mitchell,* Avro Aircraft Limited

Introduction

THE EXTREMELY RIGID geometric requirements demanded by supersonic aircraft have greatly increased the complexity of our future aircraft. It has resulted in a large increase in technical manpower required, with a resulting high cost. Very thin wings, low aspect ratio wings, smaller diameter fuselages, high control surface loads, and high pressures and temperatures form part of the aerodynamic requirements which must be met. The job facing the structures engineer is to produce a structure meeting all the rigid aerodynamic requirements but with a weight lower than that of preceding aircraft structures. The task is both difficult and challenging, requiring large groups of engineers working in close cooperation. The work is characterized by rational analysis rather than by broad assumptions which in the past have been satisfactory. Let us examine the major structural problems separately.

Load Analysis

The problem of analyzing complex low aspect ratio wings and fuselage combination must be solved for on a rational basis. The fuselage or center section can no longer be assumed to be a rigid support for the wing but bends under load, thereby influencing the load distribution in the wing to a large extent. The fuselage is then an elastic support. The displacement of the elastic support is dependent on the magnitude of load in the fuselage which is, in turn, tied into the load in the wing. (See Fig. 1.)

It is evident that the fuselage-wing combination must be analyzed as a complete complex redundant structure. The days when we could analyze the wing separately from the center section are past. Then the problem facing the structures engineer was clear, the solution to the problem not so clear.

There are different theoretical methods of approach to the problem—for example, the method advocated by D. Williams in RAE *Structures Report 156* which concentrates on solving for deflections. This method is certainly satisfactory for aeroelastic problems, but it does not satisfactorily produce stress distributions; to work from deflections to stress is at best inaccurate and at the worst impossible. Stress concentrations of a local nature cannot be sensed by deflections; however, it is common knowledge that quite crude assumptions concerning the stress distribution yield displacements which favorably compare with experiment.

Hence it was decided to calculate directly for stresses and to compute displacements from known stresses. The wing was considered to act as a plate (a two-dimensional problem) rather than as a beam (a one-dimensional problem) as is customary for straight or swept wings with relatively small taper. In brief, the method of analysis assumes an approximate moment distribution so as to satisfy the equilibrium conditions exactly while leaving strains still incompatible. This assumed distribution was corrected by several properly chosen self-equilibrating groups of internal loads akin to the stress functions of the Southwell theory of plates, their magnitude being determined by the Castigliano theorem. By solving a larger number of linear equations, the stresses were obtained and the deflections computed. The problem was set up in a matrix form.

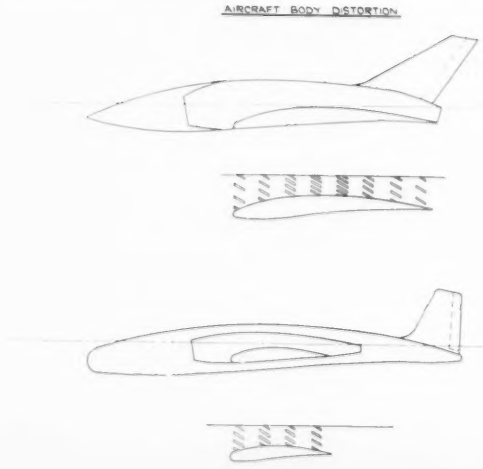


FIG. 1.

Presented at the Structures Session, CAI-IAS International Meeting, Ottawa, Canada, Nov. 3–4, 1955.

* Chief Stress Engineer.

Air loads were applied as a large number of concentrated loads. Due effect of taper, oblique panels, and Poisson's ratio was included. The use of high-speed digital computers was essential; even then it was not apparent that the computation facilities were reliable enough to allow the handling of matrices of the order 173 by 173.

Versatility was absolutely essential in such a large analysis; it must be a tool for the structures engineer to use, too often such an analysis can become a burden.

The first step to meet this requirement was to solve for the unknowns on a unit load basis. With this type of solution and with the use of high-speed digital computers it was possible to obtain the stress distributions and shapes with extremely little effort for a multitude of aerodynamic cases.

The characteristic of a matrix solution and a unit load solution also allows the use of self-equilibrating loads to represent changes of structure stiffness. There are obvious limitations to this type of repair, and complete versatility in relation to design changes is not possible. This weak point had to be remedied in some way. The only solution was to carry on an independent analysis, using proved methods of analysis but with broad assumptions to set closely the main structural members. This is where general engineering skill and experience must play important parts.

It has been found that the two types of analysis complement each other and provide a good check. This approximate analysis was also necessary to produce detail stress distributions within the framework of the matrix.

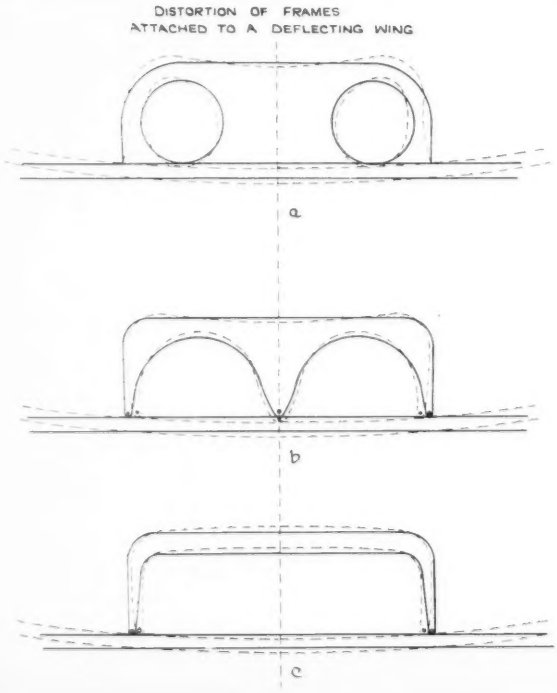


FIG. 2.

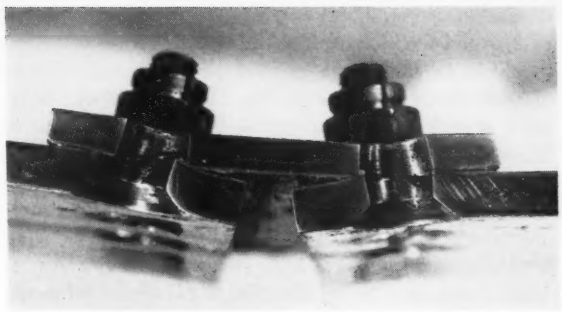


FIG. 3.

SHAPES

Supersonic aircraft employing thin wings are subject to large distortions under flight loads. This structural distortion under load has been recognized as an additional hazard to structural integrity and has necessitated its acceptance as a major design requirement.

There are several aspects concerning shapes which must be considered—for example, secondary or induced stresses into fuselage frames due to bending and twisting of the wing.

Because of compression stresses in the upper surface and tension stresses in the lower surface the wing takes a well-defined shape. A fuselage former attached to this wing will distort in some manner. Since the former is extremely light compared to wing skins, the restraining loads on the wing are extremely light, but the stresses induced into the frame can be rather large. It is possible to reduce the magnitude of the induced stresses by careful design.

Fig. 2(a) shows the worst possible arrangement. This type of arrangement could cause failure of the former at quite low wing stresses. Fig. 2(b) shows an important design improvement. The induced stresses are still significant, however. Fig. 2(c) shows an optimum arrangement.

Assuming that all possible efforts have been made to reduce the induced stresses, the structures engineer is faced with the problem of making a frame good for static loads as well as induced loads. Since the induced stresses are a direct function of the stiffness of the frame, there is no easy solution. The objective is clear, however; the stiffness must be kept as low as possible, and the allowable stresses must be kept high. A trial-and-error method was found to be most satisfactory. A frame was sized for static loads and the stiffness calculated. The induced stresses were then calculated and superimposed on the statically determined stresses. This operation was repeated until a satisfactory set of stresses was obtained. Accurate stiffness calculations and control of stiffness are absolutely essential. Increased stiffness of the frames due to poor analysis or manufacturing tolerances would cause an increase of loads into the frame which would cause premature failure of the attaching structure.

A more difficult analytical problem regarding shapes is the transition problem between a deflecting structure

as shown in Fig. 2 and a more rigid type of former that one would find forward of the wing. Since it was not possible to make the solid type of fuselage former flexible enough to absorb the distortion, it was necessary to use specially designed frame or frames to reduce distortions to an acceptable value. These frames were designed almost entirely from the stiffness point of view, and by use of them it was possible to control the distorted shapes.

One thing is clear: The structures engineer must have a complete grasp of stiffness and distorted shapes as he has in the past controlled strength. This has increased by several times the technical man-hours required.

Fatigue

Fatigue problems will continue to receive more attention by the structures engineer. It is generally agreed that one cannot afford a weight penalty to improve the fatigue life of a fighter aircraft. It is, however, important that the best fatigue life to weight ratio be obtained and that the structure have a uniformity of fatigue life—i.e., there should be no point where the stress concentration factors greatly exceed the average factor.

This latter requirement has caused some interesting problems in relation to thick wing skins on supersonic aircraft. Fig. 3 shows a typical spanwise lap joint that has been proved to be particularly bad from a fatigue point of view. The offset of load from the skin to the joint plate causes extremely high local stresses in both plates. Fatigue testing was considered necessary earlier in the design stages of the aircraft in order to obtain some design allowables for these joints. Fig. 3 is a photograph of a joint that has been high loaded and clearly shows the distortion of the plates and the elongation of the bolt in the holes.

As was suspected, the joints were proved to be unsatisfactory in the highly loaded areas of the wing and it became necessary to investigate alternative types of joints.

Fig. 4 shows the result of this investigation. Type "A" is a normal lap joint. Type "B" uses a high heat-treat steel strap just below the skin. This method did not improve the offset but did put the steel in the high stressed area. Since steel has a much higher endurance limit than aluminum, there was a significant improvement in the fatigue life of the joint.

Type "C" is, however, the optimum arrangement. A thin steel strap is used externally by machining a step in the skin. This arrangement reduces the offset to a minimum and provides satisfactory fatigue characteristics.

The necessary use of large high-strength forgings in the thin wings and fuselages has produced a serious fatigue problem. The characteristics of this material differ greatly in the longitudinal grain, transverse grain, and short transverse grain. Careful control of stresses,

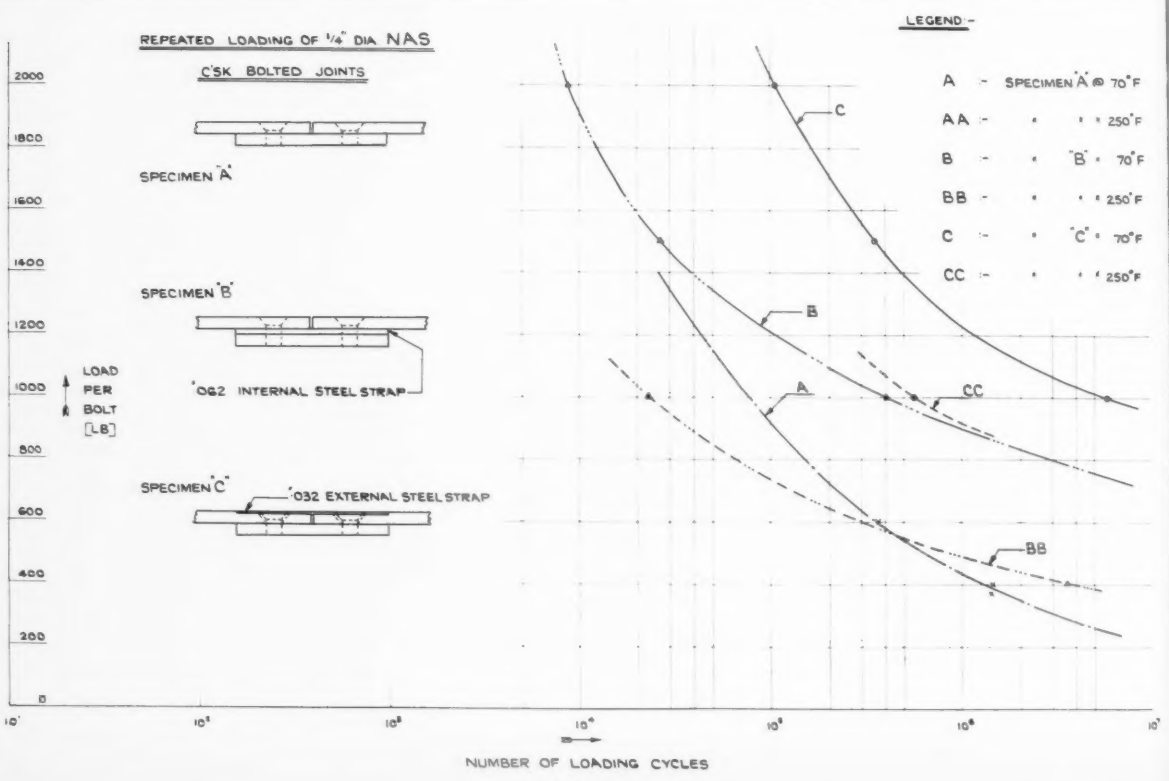


Fig. 4.

especially in the short transverse grain direction, is essential in providing a satisfactory fatigue life.

Careful detail design and detail stress analysis are probably the most important single factors in providing a satisfactory fatigue life. Detail stress analysis of complicated fittings is difficult and time-consuming, and although a large amount of work may not be justified to provide static strength, it is necessary to provide satisfactory fatigue life.

However, analytical work will not replace fatigue testing. Too often the results of fatigue testing do not agree with theory. Relatively insignificant parameters may greatly affect the fatigue life of an aircraft component.

Early and continued fatigue testing and development is a major aspect in providing structural integrity.

Internal Pressures

Supersonic aircraft are literally flying pressure vessels. In the past, the only significant pressures from a structural point of view have been in the cockpit and fuel tanks. Now the complete aircraft structure is subject to variations of pressure and depressions of quite high magnitude.

This fact has influenced the structural design greatly, and a great deal of ingenuity has been required in order to handle the problem with a minimum of weight penalty.

The analytical questions have not been severe, although the problem has proved to be particularly interesting in several respects. It has opened a completely new field in structural research aimed at providing the optimum strength to weight ratio. A considerable amount of research has been done on optimum structures using varying parameters of end load, shear, and torque. The addition of pressures into the set of equations has a pronounced effect on the final configuration of the optimum arrangement. Since the amount of weight involved is large, obtaining the optimum arrangement was absolutely necessary.

Analytically, the stability of distorted depression vessels proved to be the most significant problem.

The problem is primarily a detail one, and for that reason it is impossible to cover it in this paper in a satisfactory way. It has been mentioned primarily because it is an additional aspect that has greatly influenced the structural design of supersonic aircraft.

Landing Gear

It would be reasonable to suspect that landing gears would not present any unusual problem in supersonic aircraft. This is however far from the truth. The exacting geometric requirements complicate the undercarriage problem tremendously—not only in mechanical design but also in load analysis.

The gear must be stored in a limited space envelope; it must cut the very minimum of prime structure, and therefore it cannot be properly braced. It must be long enough to allow high angles of attack for take-off and landing of the aircraft, and yet it must be capable of bringing to rest heavy, high-speed aircraft on normal runways with the minimum of weight penalty.

The dynamic condition of a landing gear during wheel spin-up has been a well-known phenomenon for many years. However, in the past it has been satisfactory to assume the gear as a cantilever beam fixed at the aircraft structure. Recommended magnification factors of ANC-2 are based on this type of gear.

The problem of the dynamics of an elastic gear mounted on an elastic structure is an enormously more complicated one. The method for calculation of natural frequencies, stiffnesses of U/C strut, and wing has been developed. An equivalent vibrating system of U/C strut-wing has been introduced with six degrees of freedom. The frequency equations for the system have been solved by interation method for the two lowest frequencies. The structural-aerodynamic damping has been taken into account by multiplying the undamped responses by a calculated decay factor.

Design parameters also had to be altered to derive the optimum dynamic characteristics. Metering pins, spring-controlled valves, and geometric arrangement of fore and aft bogie can be used to alter the forcing function due to spin-up and thereby significantly alter the dynamic characteristics. Figs. 5 and 6 show a plot of the displacement function with a corresponding forcing function. The variation of forcing function alters the displacement function considerably. Steps in the forcing function curve are characteristic of a fore and aft bogie where one wheel contacts the ground first and proceeds to spin-up before the second wheel hits. This has the advantageous effect of extending the time of spin-up. The analysis included dynamics of the gear-wing in the vertical direction, as well as in the horizontal.

The amount of technical man-hours required for this program is approximately 15 times that required for a more conventional gear in a low-speed aircraft.

Heat

Aerodynamic heating has been much publicized of late as a major structural problem in supersonic aircraft. A brief discussion of this problem then should be sufficient for this paper.

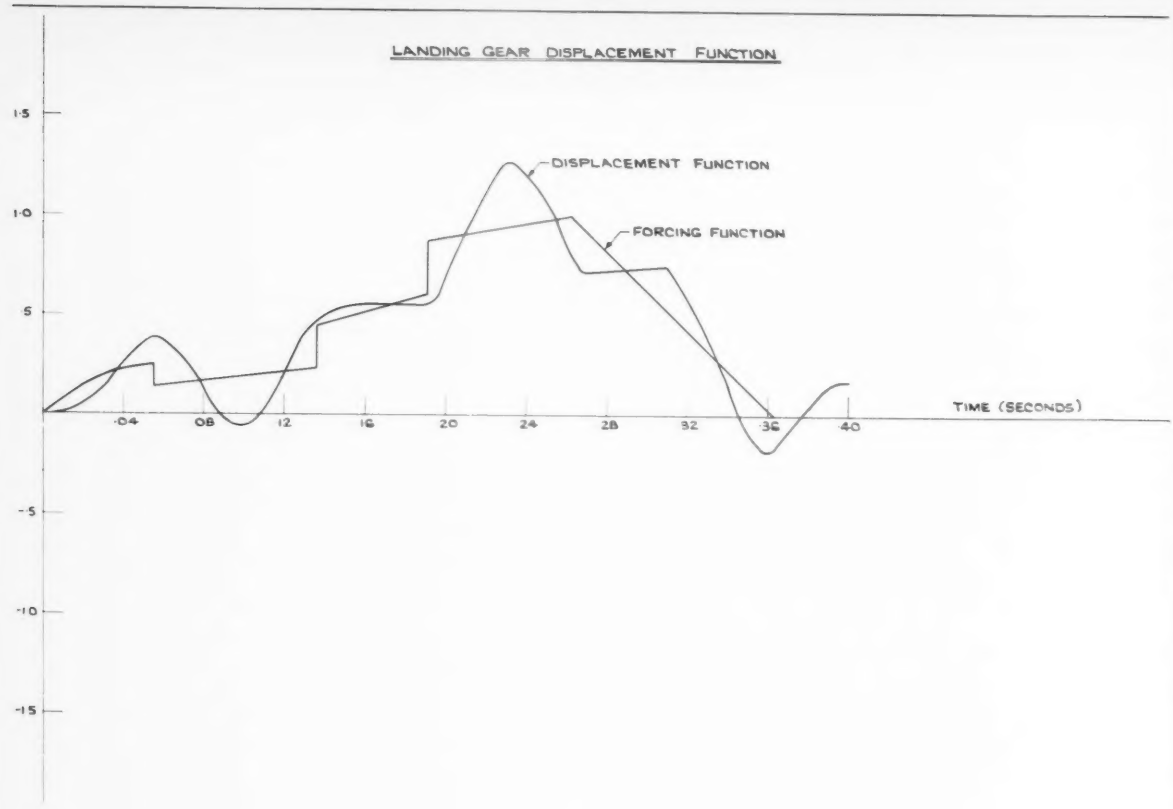
There are three main aspects of heat that must be considered:

(1) *Strength Properties*

Elevated temperatures have the effect of reducing the allowable stresses and elasticity of all metals. This is not a difficult problem to cope with; however, considerable laboratory testing is necessary to produce full sets of material properties at various elevated temperatures.

(2) *Transient Temperatures*

The transient temperature problem is by far the most difficult that will have to be tackled. The flow of heat


LANDING GEAR DISPLACEMENT FUNCTION
DISPLACEMENT FUNCTION
FORCING FUNCTION
TIME (SECONDS)
1·5
1·0
·5
-·5
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·04
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FIG. 5.

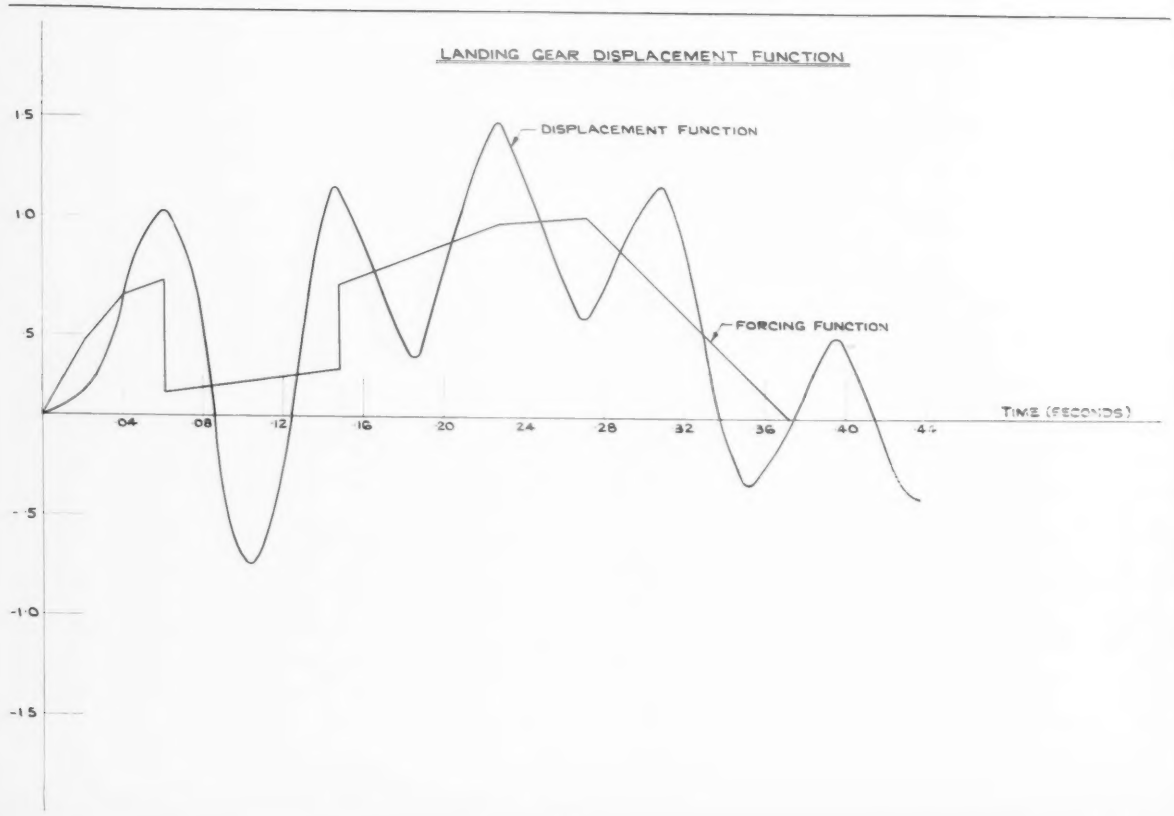
LANDING GEAR DISPLACEMENT FUNCTION
DISPLACEMENT FUNCTION
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FIG. 6.

through a structure causes a heat gradient. This gradient causes induced stresses, as well as a change of shape of the structure. Careful design is necessary to minimize the adverse effects of this temperature gradient. Thermal insulation, conductors, composite materials, and unconventional structural arrangements can be used by the designer to improve or impair the flow of heat, depending on which is the most desirable.

A large volume of experimental data will be necessary, especially in relation to thermal conductance of joints. Special techniques and methods will have to be developed to apply large amounts of heat to the test specimen under extremely close time control.

Thermocouples and strain gages will be required to measure heat and strains on a continuous trace throughout the structure.

(3) *Creep*

Creep has been listed separately here because of its importance in the elevated temperature problem. This is particularly critical with high-speed aircraft where time at temperature is likely to be a significant feature.

New Materials

The great strides being made aerodynamically must be paralleled by advances in the metallurgical field. New and better aircraft structural materials are very much in demand. New alloys are being developed which appear promising, but the development of these materials is being viewed with considerable impatience by the structures engineer.

Superhigh heat-treat steels, high-strength magnesium, new high-strength forgeable aluminum alloys, and high-strength titanium alloys appear to be promising developments. If these materials can be made available in production quantities, the success and performance of supersonic aircraft will be improved considerably.

Aircraft production departments must also take active steps in the development of new materials. Each new material presents a multitude of special problems. Development of the necessary production techniques is an important phase in the complete acceptance of a new alloy.

Conclusion

This paper covers a few of the major aspects of supersonic aircraft structure problems—and in a very broad manner. The multitude of more detail problems in itself poses as a major problem that can be solved only by large numbers of well-trained technical personnel. The job of planning, coordinating, and supervising such large numbers of technical personnel is an imposing task. Last but far from least, it requires a great deal of money not only for the analytical work but also for the testing and development associated with it.

The Floating Integrating Gyro and Its Application to Geometrical Stabilization Problems on Moving Bases

by C. S. Draper, W. Wrigley, and L. R. Grohe

Now Available as a Sherman M. Fairchild Fund Paper No. FF-13

This paper as presented in this form represents a considerable revision of the preprint version. In particular, the text and illustrations that pertain to experimental results of gyro unit tests have been given careful attention, with the object of presenting a truer picture of the relative performance capabilities of integrating gyro units, rate gyro units, and feedback integrating gyro rate indicating systems.

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The development by the aluminum industry of new products of higher elevated temperature strength and stability than air-frame alloys may now possess.

Aluminum Alloys for Elevated Temperature Service

E. H. Dix, Jr.*
Aluminum Company of America

Introduction

Aluminum alloys have been, since the spruce and wire days, the principal materials for the structural components of aircraft. With the advent of jet propulsion and high-speed aircraft, the performance of materials at elevated temperatures has received the earnest attention of those concerned with aircraft progress. It was early recognized that aluminum alloys faced certain limitations in this respect, and the search for alloys with improved elevated temperature properties has been diligent, but progress has been difficult.

No one expects the metallurgist to be able to raise the melting point of aluminum, and, since the structural aluminum alloys all achieve their high strength by heat-treatment, their strength is impaired by reheating beyond certain temperatures. Some recent developments, to be discussed later, have made available products which have a higher melting point than the conventionally prepared alloys and which have exceptionally stable properties for a long time at elevated temperatures. The problem is further complicated by variations in the time-temperature relations in different applications. The time varies from a matter of seconds for some missiles to 100 hours, 1,000 hours, or longer for piloted aircraft.

There has been a tendency to apply the over-simplified criterion of strength-weight ratio in comparing aluminum alloys with other metals, such as titanium and stainless steel, for elevated temperature service. This has led to the fairly general opinion that the days of aluminum structures for high-speed aircraft are numbered. The aluminum industry, always reluctant to lose an established use, is fighting hard to retain this business, and the situation is more favorable than has sometimes been indicated.

Research has developed new alloys and powder metallurgy products which represent distinct improvements in elevated temperature properties. These improved products have been discussed informally for several years without creating as much interest in the aircraft industry as they deserve. Perhaps the timing has been bad, or it may be a case of too little too late. It is possible that even the present aluminum alloys perform so much better at mildly elevated temperatures than some nonmetallic materials essential for high-speed aircraft—for instance, those required for transparent enclosures and radomes—that the aluminum-alloy elevated temperature problem is not yet critical.

As evidence of current interest, in March, 1955, two informative articles appeared, one from England and one from this country. Major P. L. Teed, in his article† *Metallurgy and Stratospheric Flight*, stated, "Dealing with the world as it is and not looking too far forward, a speed at stratospheric heights of 1,400 miles an hour appears to be attainable within the next 10 years!" He further indicated that at this speed at 50,000 ft., the surface of an aircraft with turbulent flow would reach a temperature of about 212°F.

In the other article,‡ by N. E. Promisel, a curve is presented indicating a somewhat higher skin temperature, slightly under 300°F., produced by the effect of aerodynamic heating at a speed of 1,400 m.p.h. at an altitude of 50,000 ft. Mr. Promisel stated, however, that recently a plane had flown at a speed of over 1,600 m.p.h., which, if maintained for a long enough time, would have raised the skin temperature to about 400°F. It is evident, therefore, that at the present time we are facing skin temperatures of from 200° to 400°F. in supersonic flight from aerodynamic heating alone. Undoubtedly, there are military planes now being designed which are expected to exceed the speeds mentioned, and therefore skin temperatures exceeding 400°F. may result. In addition to heat generated by this cause, locations always exist where there is a chance of heating from proximity to power plants and from intentional heating for the purpose of deicing and cabin heating; thus, some structural air-frame members may reach a temperature of 600°F. in piloted craft and much higher—but for a shorter time—in missiles.

Presented at the Materials and Processes Session, CAI-IAS International Meeting, Ottawa, Canada, Nov. 3–4, 1955.

* Assistant Director of Research.

† Metal Progress, Vol. 67, No. 3, pp. 85–89, March, 1955.

‡ Journal of Metals, Vol. 1, No. 3, pp. 443–447, March, 1955.

In discussing structural uses at elevated temperatures, it is well to remember that even at room temperature aluminum alloys cannot compete on a strictly tensile strength-weight basis with the best titanium alloys or high-strength steels. But aluminum alloys probably make up 80 per cent of the structure of current planes. One reason is that they possess an advantage in shear or compression where buckling is the controlling factor in design. In such applications, the low density of aluminum alloys can be exploited effectively to increase the stiffness of the parts, thus offsetting the strength advantage of the heavier metals. At what temperature will this predominance of aluminum alloys be reduced significantly? No one seems to be able to give a categorical answer to this and similar questions. However, Mr. Promisel states, "In compression plate applications where buckling is critical and, under some conditions in shear . . ., steel appears to be of dubious merit at all temperatures and aluminum has the advantage even at moderately high temperatures, possibly up to 500 or 600°F."

It is, therefore, timely to present to the aircraft industry, in a formal manner, the most up-to-date information on elevated temperature properties of current and newly developed aluminum products. The aluminum and aircraft industries have a joint responsibility to determine whether the new products have sufficient promise to justify the cost of time-consuming programs required by both industries to introduce a new product successfully.

Wrought Aluminum Alloys for Air Frames

The wrought alloys currently used in air frames may be divided into two types. The aluminum-zinc-magnesium-copper alloys (7075, X7178, and X7079) in the -T6 temper have the highest strength at room temperature, but, as is well known, the strength falls off rapidly at temperatures exceeding 200° to 250°F., especially after long times at temperature. Alloys 7075 and X7178 are used in the form of sheet, plate, and extrusions, and 7075 and X7079 are used as forgings. Alloy 7075-T6* will be used as representative of this group. The aluminum-copper-magnesium alloys (2014 and 2024) represent the second type and are the presently preferred alloys if elevated temperatures are anticipated. Alloy 2014 is currently used in the artificially aged temper (-T6); alloy 2024 is generally used in the naturally aged temper (-T4). Both alloys are available as extrusions, sheet, and plate; however, for aircraft, 2014 alloy sheet is generally in alclad form. Alloy 2014 is also extensively used for forgings. For elevated temperature applications, the -T6 temper is preferred not only because of the higher initial strength but also because of the greater stability of the properties; otherwise aging occurs at such temperatures. Also, if the initial temper is -T4, an intermediate microstructural condition occurs during aging which results in a lowered resistance to corrosion. Further aging to the full -T6 temper restores the resistance to corrosion.

Forging Alloy 2618-T61

For forgings in power-plant applications, alloy 2618-T61† has received favorable consideration from the time it was introduced into the United States from England in the specifications for the American-made Nene engine. Alloy 2014-T6 has been used extensively and satisfactorily for forgings in similar applications for many years.

New Experimental Alloys

A new alloy, X2219-T6, is an independent development in the United States, although it has copper and manganese contents similar to the British alloy RR57. The alloy contains, in addition to the copper (6.0 per cent) and manganese (0.3 per cent), small quantities of vanadium and zirconium and is covered by a recently issued United States patent.‡ It has outstanding properties at temperatures above 500°F. At the present time this alloy is experimental, as indicated by the "X" status, for extrusions and forgings. Should sufficient demand develop, it could also be made available for sheet and plate.

Alloy M237,** as its designation indicates, is still in the laboratory stage, and it has not yet been determined whether it can be produced commercially. However, it is being considered for sheet, plate, and extrusions. Its properties are such as to make it of considerable interest in the temperature range 300–400°F., which, for the next few years, seems to be the most important range.

Aluminum Powder Metallurgy Products

Following the discovery in Switzerland of the unique characteristics of wrought products made from fine aluminum flake powder containing appreciable amounts of aluminum oxide, there has been extensive development in both the United States and Europe of products of this type. At the present time, Alcoa is experimentally producing compacts up to 21 in. in diameter and weighing up to 800 lbs. These compacts are fabricated by extrusion in the same manner as ingots produced by the conventional casting process. The extrusions may, if desired, be further forged or rolled into sheet.

The properties of these products vary with the particle size and oxide content. The smaller the particle size and the higher the oxide content, the greater the strength and the lower the workability and ductility of the product. Alcoa has produced experimental quantities of sheet, foil, extrusions, and forgings which are being tested by a number of companies. Several ap-

* U.S. Patent 2,240,940.

† U.S. Patent 2,522,575.

‡ U.S. Patent 2,706,680.

** Patent pending.

TABLE 1
Nominal Compositions of Wrought Aluminum Alloys

	7075	2024	2014	2618	X2219
Cu	1.6	4.5	4.5	2.2	6.0
Fe	--	--	--	1.1	--
Si	--	--	0.9	--	--
Mn	--	0.65	0.8	--	0.3
Mg	2.5	1.5	0.5	1.6	--
Zn	5.7	--	--	--	--
Cr	0.25	--	--	--	--
Ni	--	--	--	1.05	--
Ti	--	--	--	0.07	--
V	--	--	--	--	0.10
Zr	--	--	--	--	0.15

plications involving extrusions and forgings have reached the stage of commercial use.

It should be emphasized, however, that since the manufacture of compacts is not yet carried out under production conditions, large quantities of these products can be made available only after production facilities for compacts are established. So far, the demand for the products has not justified taking this step. The product, which is being investigated most extensively, is identified as M257. It is readily forgeable, and sheet of this material has a formability about equivalent to that of 7075-T6. Another product of higher strength has been designated M276. It is more difficult to work than M257 and less experience has been gained with it, but a product with its properties can be made available. Because of the high oxide content, brazing or fusion welding procedures have not yet been successfully worked out for the APM (Aluminum Powder Metallurgy) products.

Above about 600°F., these APM products have strengths superior to any conventionally produced aluminum alloys, and, since aluminum oxide is insoluble in solid aluminum, the stability of properties is remarkable. Furthermore, since the powder is unalloyed, it has a melting point as high as that of pure aluminum. Even when heated above the melting point of aluminum, the APM products maintain their shape to a considerable extent—that is, they do not become liquid and flow as conventional alloys do.

Casting Alloys

There are three standard casting alloys being used for elevated temperature service and one experimental alloy of the "X" status. The oldest alloy, 142, is the British "Y" alloy of World War I. It has stood the test of time because of its good elevated temperature properties. Alloys 355 and A355 are of the aluminum-silicon-magnesium-copper type and hence have excellent casting characteristics. Alloy A355 contains, in addition to the elements mentioned, 0.8 per cent of both manganese and nickel. The new alloy XA140* contains high copper (8.0 per cent) and magnesium (6.0 per cent) with the addition of manganese and nickel (0.5 per cent each). At 600°F., this new alloy exhibits tensile and fatigue strengths superior to those of other commercial aluminum casting alloys. It is also outstanding in its resistance to loss of tensile properties upon prolonged heating.

Presentation of Data

The data on the wrought alloys just discussed, available at Aluminum Research Laboratories, are given in the Tables. Table 1 lists the nominal chemical compositions of the wrought alloys to be discussed, with the exception of that of M237 which is omitted because the alloy has no commercial standing. This laboratory composition is a modification of that of alloy X2219. Its elevated temperature properties are sufficiently different from those of X2219 to justify presenting the properties of both in order to determine which is most acceptable to the aircraft industry.

Table 2 gives the tensile properties from room temperature to 700°F. after periods of time—at temperature—of from 1/2 to 10,000 hours. The data on the standard air-frame alloys (7075-T6, 2024-T4, and 2014-T6) are the weighted averages of tests of a number of lots of products. In the case of the first two alloys, the data include tests on commercially produced rolled-and-drawn rod, and for the 2014-T6 on both rolled-and-drawn rod and forgings. The properties for 2618-T61, X2219-T6, and M237 are more limited and are confined to tests on forgings only. The APM products were tested in the form of extrusions.

Table 3 gives the stress required to produce stress rupture in 1 to 1,000 hours and creep of 0.1 to 1 per cent in the same periods of time. The data for 7075-T6 and 2024-T4 were obtained from sheet and rolled-and-drawn rod and, for 2014-T6, from forgings and rolled-and-drawn rod. Data for 2618-T61, X2219-T6, and M237 were obtained from forgings and APM products from extrusions. Creep, as reported in this table, is the flow or plastic deformation that occurs with time under a constant load, after the initial deformation resulting from the application of load. Compressive creep tests made at Cornell Aeronautical Laboratory, Inc., indicate that compressive creep follows approximately the same pattern as tensile creep.

In Table 4 the fatigue properties are presented at temperatures up to 600°F. For 7075-T6, these properties were obtained on rolled-and-drawn rod; for 2024-T4 on extruded bar; for 2014-T6 on forgings, rolled-and-drawn rod, and extrusions; for 2618-T61,

* Patent pending.

X2219-T6, and M237 on forgings; and for APM products on extrusions.

Figs. 7 and 8 give the room temperature tensile properties of the various alloys after heating for 100 and 1,000 hours at various temperatures. These data were obtained from tests of sheet, plate, and rolled-and-drawn rod of 7075-T6; plate of 2024-T4; sheet, plate, forgings, and rolled-and-drawn rod of 2014-Y6; forgings of 2618-T61; sheet of X2219-T6 and M237; and extrusions of the APM products.

The tensile yield strength data from Tables 1 and 2 have been plotted in Figs. 1 and 2, for 100 and 1,000 hours respectively. The values for compressive yield strength do not differ greatly from the tensile yield strength at room temperature and come even closer together as the testing temperature increases, as indicated by tests made at Armour Research Foundation. In Figs. 3 and 4, the tensile yield strength has been plotted against time at temperature, for temperatures of 300° and 600°F. respectively. These latter curves are of particular interest in indicating the degree of stability of the tensile properties during prolonged heating.

Discussion of Data

A comparison of the elevated temperature characteristics of the various alloys under discussion can best be started with a consideration of the well-known airframe alloys 2024 and 2014. The tensile yield strengths of 2024 are given for simplicity in only the -T4 temper. The yield strength of the -T4 and -T6 tempers are equivalent above a temperature of about 375°F. after heating about 10 hours, which is the usual artificial aging treatment for this alloy. The same is true after 100 hours. From Table 2 it will be observed that at 300°F. and lower, alloy 2014-T6 appears to be stronger than 2024-T4. The curves of tensile yield strength (Figs. 1 and 2) cross after 100 hours at 390°F. and after 1,000 hours at 325°F. At 400°F. and higher, alloy 2024-T4 is, in general, superior in strength to 2014-T6, the exception being the yield strength after one-half hour at 400° and 500°F.

The creep and stress rupture properties are more complicated. From Table 3 it would seem that at 300°F. alloy 2014-T6 has an advantage over 2024-T4 in creep. In stress rupture at this temperature, these two alloys are comparable. At 400°F., alloy 2014-T6

Table 2
Tensile Properties of Some Aluminum Alloys at Elevated Temperatures

	Tensile Strength, PSI	Yield Strength, PSI	Elong. in 2 in., %	Tensile Strength, PSI	Yield Strength, PSI	Elong. in 2 in., %	Tensile Strength, PSI	Yield Strength, PSI	Elong. in 2 in., %	Tensile Strength, PSI	Yield Strength, PSI	Elong. in 2 in., %
Alloy	7075-T6			2024-T4			2014-T6			2618-T61		
Room Temperature	82 000	72 000	11	68 000	46 000	22	70 000	60 000	13	64 000	54 000	10
212°F - 1/2 HR	72 000	64 000	15	61 000	43 000	23	66 000	56 000	13	64 000	54 000	10
100 HR	72 000	64 000	14	63 000	45 000	23	67 000	57 000	13	64 000	54 000	10
1000 HR	72 000	65 000	14	62 000	45 000	23	68 000	60 000	13	64 000	55 000	9
10000 HR	65 000	60 000	12	62 000	44 000	20	69 000	63 000	14	65 000	55 000	9
300°F - 1/2 HR	57 000	51 000	20	56 000	40 000	28	59 000	51 000	13	57 000	51 000	14
100 HR	48 000	44 000	20	58 000	46 000	19	59 000	54 000	13	56 000	52 000	13
1000 HR	32 000	29 000	25	52 000	44 000	20	56 000	51 000	14	54 000	48 000	13
10000 HR	25 000	21 000	30	43 000	36 000	20	47 000	40 000	15	50 000	45 000	13
400°F - 1/2 HR	38 000	34 000	20	51 000	36 000	25	46 000	43 000	13	46 000	43 000	14
100 HR	17 000	15 000	40	37 000	31 000	22	33 000	29 000	20	39 000	34 000	17
1000 HR	15 000	13 000	50	31 000	27 000	24	23 000	18 000	30	36 000	31 000	20
10000 HR	14 000	12 000	50	26 000	21 000	25	18 000	12 000	35	33 000	30 000	25
500°F - 1/2 HR	36 000	14 000	35	29 000	23 000	22	28 000	25 000	18	29 000	26 000	25
100 HR	12 000	9 500	50	20 000	15 000	30	15 000	12 000	30	21 000	17 000	36
1000 HR	11 000	9 000	50	16 000	12 000	42	12 000	10 000	40	19 000	13 000	45
10000 HR	11 000	9 000	65	14 000	9 500	46	11 000	8 500	45	---	---	--
600°F - 1/2 HR	19 500	7 000	55	15 000	12 000	35	10 000	9 000	30	21 000	18 000	30
100 HR	8 500	6 500	80	10 000	7 500	55	6 000	5 500	50	11 000	9 500	55
1000 HR	8 500	6 500	80	8 000	6 500	70	5 000	4 500	60	9 000	8 000	75
10000 HR	8 500	6 500	80	7 500	6 000	75	4 500	4 000	65	7 500	6 500	80
700°F - 1/2 HR	9 500	5 000	60	7 500	6 000	65	6 000	5 000	50	8 500	6 500	50
100 HR	6 000	4 500	65	6 500	4 500	95	5 000	4 000	60	6 500	4 000	--
1000 HR	6 000	4 500	65	5 000	3 500	100	4 500	3 500	65	4 000	3 500	--
10000 HR	6 000	4 500	65	5 000	3 500	100	4 500	3 500	70	---	---	--
Alloy	X2219-T6			M237			M257 (APM)			M276 (APM)		
Room Temperature	62 000	43 000	16	69 000	53 000	12	38 000	25 000	17	51 000	34 000	7
212°F - 1/2 HR	---	---	--	---	---	--	---	---	--	---	---	--
100 HR	---	---	--	---	---	--	---	---	--	---	---	--
1000 HR	---	---	--	---	---	--	---	---	--	---	---	--
10000 HR	---	---	--	---	---	--	---	---	--	---	---	--
300°F - 1/2 HR	52 000	41 000	22	60 000	50 000	16	---	---	--	---	---	--
100 HR	52 000	42 000	22	60 000	49 000	16	---	---	--	---	---	--
1000 HR	50 000	37 000	19	60 000	49 000	17	---	---	--	---	---	--
10000 HR	45 000	32 000	19	58 000	47 000	16	---	---	--	---	---	--
400°F - 1/2 HR	39 000	34 000	24	51 000	44 000	19	21 000	19 000	16	32 000	27 000	6
100 HR	38 000	28 000	21	46 000	38 000	20	21 000	18 000	16	32 000	27 000	6
1000 HR	38 000	27 000	21	37 000	31 000	24	21 000	18 000	16	31 000	26 000	6
10000 HR	---	---	--	---	---	--	---	---	--	---	---	--
500°F - 1/2 HR	29 000	24 000	23	34 000	31 000	25	19 000	16 000	17	26 000	23 000	7
100 HR	29 000	22 000	24	26 000	23 000	28	19 000	16 000	17	26 000	23 000	7
1000 HR	29 000	22 000	24	26 000	21 000	27	19 000	16 000	17	26 000	23 000	7
10000 HR	---	---	--	---	---	--	---	---	--	---	---	--
600°F - 1/2 HR	21 000	17 000	25	18 000	16 000	25	16 000	14 000	15	22 000	20 000	6
100 HR	20 000	15 000	25	15 000	13 000	30	16 000	14 000	12	22 000	20 000	6
1000 HR	18 000	14 000	27	15 000	13 000	29	16 000	14 000	17	22 000	20 000	5
10000 HR	---	---	--	---	---	--	---	---	--	---	---	--
700°F - 1/2 HR	12 000	10 000	39	---	---	--	14 000	13 000	9	19 000	18 000	4
100 HR	8 500	8 000	62	---	---	--	14 000	13 000	9	19 000	18 000	4
1000 HR	---	---	--	---	---	--	14 000	13 000	9	19 000	18 000	4
10000 HR	---	---	--	---	---	--	---	---	--	---	---	--

TABLE 3
Creep and Stress Rupture Values for Aluminum Alloys at Elevated Temperatures

		7075-T6	2024-T4	2014-T6	2618-T61	X2219-T6	M237	M257 (APM)	M276 (APM)
		STRESS, PSI, FOR CREEP AND RUPTURE							
212°F --RUPTURE IN	1 HR	71 000	---	67 000	---	---	---	---	---
	10 HR	68 000	---	64 000	---	---	---	---	---
	100 HR	63 000	63 000	60 000	---	---	---	---	---
	1000 HR	56 000	59 000	58 000	---	---	---	---	---
CREEP - 1.0% IN	1 HR	63 000	---	59 000	---	---	---	---	---
	10 HR	59 000	---	58 500	---	---	---	---	---
	100 HR	56 000	---	58 000	---	---	---	---	---
	1000 HR	52 000	---	56 000	---	---	---	---	---
300°F - RUPTURE IN	1 HR	57 000	---	57 000	53 000	---	---	---	---
	10 HR	49 000	---	52 000	49 000	---	---	---	---
	100 HR	37 000	52 000	49 000	44 000	---	---	---	---
	1000 HR	23 000	40 000	40 000	38 000	---	40 000	---	---
CREEP - 1.0% IN	1 HR	50 000	46 000	54 000	49 000	---	---	---	---
	10 HR	44 000	45 000	52 000	48 000	---	---	---	---
	100 HR	35 000	43 500	49 000	43 000	---	41 000	---	---
	1000 HR	22 000	39 000	40 000	---	---	40 000	---	---
0.5% IN	1 HR	38 000	41 000	44 000	48 000	---	42 000	---	---
	10 HR	35 000	40 000	42 000	47 000	---	41 000	---	---
	100 HR	27 000	39 000	38 000	42 000	---	40 000	---	---
	1000 HR	20 000	---	34 000	---	---	38 000	---	---
400°F - RUPTURE IN	1 HR	---	---	---	32 500	31 000	---	---	---
	10 HR	19 000	33 000	33 000	28 000	29 000	38 000	18 000	26 000
	100 HR	14 000	26 000	25 000	24 000	26 000	31 000	17 000	23 000
	1000 HR	9 600	18 000	14 000	21 000	24 000	25 000	16 000	20 000
CREEP - 1.0% IN	1 HR	19 000	---	35 000	29 000	29 000	---	18 000	---
	10 HR	17 000	---	33 000	25 500	26 000	---	17 000	24 000
	100 HR	13 000	21 000	24 000	21 500	24 000	27 000	16 000	22 000
	1000 HR	9 400	15 000	11 000	19 000	23 000	---	---	20 000
0.5% IN	1 HR	18 000	---	35 000	28 000	27 000	---	17 500	25 000
	10 HR	16 000	24 000	33 000	24 500	23 000	30 000	16 500	23 000
	100 HR	12 000	19 000	24 000	21 000	20 000	26 000	15 000	21 000
	1000 HR	---	13 000	11 000	18 500	---	---	---	19 000
0.2% IN	1 HR	16 000	24 000	35 000	27 000	23 000	31 000	15 000	21 000
	10 HR	12 000	20 000	32 000	23 500	19 000	27 000	14 000	20 000
	100 HR	9 500	14 000	21 000	20 000	---	---	---	---
	1000 HR	---	---	---	---	---	---	---	---
0.1% IN	1 HR	12 000	20 000	32 000	26 000	19 000	27 000	---	---
	10 HR	9 900	14 000	27 000	22 000	---	---	---	---
	100 HR	---	---	16 000	19 000	---	---	---	---
	1000 HR	---	---	---	15 000	---	---	---	---
600°F - RUPTURE IN	1 HR	---	---	---	10 000	---	---	---	---
	10 HR	---	7 000	5 000	7 500	14 000	11 000	13 000	15 000
	100 HR	4 400	4 400	3 500	5 000	9 500	8 700	11 500	14 000
	1000 HR	3 500	2 700	2 500	3 000	7 000	7 000	10 000	12 000
CREEP - 1.0% IN	1 HR	---	---	5 700	9 000	---	---	---	---
	10 HR	4 800	5 500	4 000	7 000	11 000	10 000	12 500	---
	100 HR	3 700	3 600	2 800	4 500	9 000	8 000	11 000	---
	1000 HR	2 700	---	---	2 500	---	---	10 000	---
0.5% IN	1 HR	---	6 100	4 900	8 500	13 000	---	14 000	---
	10 HR	4 400	5 000	3 400	6 500	10 000	9 600	12 000	14 500
	100 HR	3 300	3 000	2 400	4 000	8 000	7 300	10 500	13 000
0.2% IN	1 HR	5 000	5 500	4 000	7 000	10 500	11 000	11 000	14 000
	10 HR	3 800	3 300	2 800	6 000	8 500	7 500	10 500	12 000
	100 HR	---	1 800	2 000	3 000	6 700	---	---	---
0.1% IN	1 HR	4 200	3 700	3 200	6 500	9 000	7 500	---	12 000
	10 HR	---	---	2 200	4 000	7 500	---	---	---

continues to show an advantage in creep over 2024-T4 and is comparable in stress rupture, although in both properties 2024-T4 shows some superiority for longer times. At 600°F., 2024-T4 shows an advantage in both creep and stress rupture over 2014-T6. Referring to Table 4, 2024-T4 is shown to have an advantage over 2014-T6 in fatigue strength. Data for 2024 in the -T6 temper are not available for creep, stress rupture, and fatigue, but these properties should not differ appreciably from those of the -T4 temper after artificial aging has taken place during heating.

To sum up so far, it would seem that the characteristics of 2014-T6 and 2024-T6 or of 2024-T4, after heating at temperatures and times in excess of those required to complete artificial aging, are similar, and, except as noted previously, there is little to choose between these two alloys for elevated temperature service. It will be convenient, therefore, to consider these alloys as a basis for comparison.

The aluminum-magnesium-zinc-copper alloys may be discussed briefly, using 7075-T6 as typical of their behavior at elevated temperatures. Fig. 1 shows that after 100 hours at temperature 7075-T6 loses its strength advantage at about 250°F. Fig. 3 clearly shows how rapidly this product loses its strength at 300°F., and at 600°F. (Fig. 4) it is at the bottom of the list after one-half hour; although at this temperature 2024 and 2014 are not greatly different, especially after 100 hours. These aluminum-magnesium-zinc-copper alloys are not recommended for service at temperatures above 250°F.

Alloy 2618-T6, which at present is used only for forgings, is extremely close in elevated temperature properties to 2014 and 2024. Its tensile yield strength is slightly higher at 400° to 500°F. after about 100 hours at temperature (Fig. 1). At 400°F., its creep and stress rupture strengths are in general comparable with those of 2014 and 2024 alloys (Table 3). At 600°F., however, its creep and stress rupture characteristics are definitely superior to those of 2014 and 2024. In fatigue strength (Table 4), its lies between 2014 and 2024 at 400° and 500°F. and is superior to both at 600°F. for a life up to a million cycles.

Next in order of interest with increasing temperature is alloy M237. The tensile yield strength of this alloy after 100 hours at temperature is highest from about 375° to 500°F. (Fig. 1) of any of the alloys tested. Its greater stability at 300°F. is clearly shown by Fig. 3 where its yield strength after 10,000 hours at temperature is some 8,000 to 10,000 psi higher than for 2014 or 2024 and several thousand psi higher than for 2618-T6. At 300°F., its creep and stress rupture strengths are comparable to 2014 and 2024. At 400°F., its creep strength is also comparable, but its stress rupture strength is the highest of any of the alloys tested. At this temperature, its fatigue strength ranks with 2024-T4 and 2618-T6. At 600°F., it is on a par with 2618-T61 and superior to 2024-T4 up to a life of a million cycles.

With further increase in temperature level, X2219-T6 should be considered. Referring again to the tensile yield strength curves of Figs. 1 and 2, it will be seen that X2219-T6 shows a slight superiority in tensile yield strength over M237 after 100 hours of heating at 525° to 600°F. and is comparable with it after 1,000 hours of heating at 475° to 600°F. This superiority in tensile yield strength at 600°F. is again illustrated in Fig. 4, although the difference seems to decrease with increasing time at temperature. In creep and stress rupture strength (Table 3), M237 is superior to X2219-T6 at 400°F., but at 600°F. alloy X2219-T6 shows a slight superiority. In fatigue strength (Table 4), X2219-T6 is nearly as good as M237 or 2618-T61 at both 400° and 600°F.

As was stated in the INTRODUCTION, the aluminum powder metallurgy products are in a class by themselves in their behavior at elevated temperatures. Figs. 1 and 2 show how well the tensile yield strengths of these products hold up with increasing temperature, and Fig. 4 shows their remarkable stability at 600°F. In tensile yield strength, the APM product M257 shows marked superiority at temperatures above 625°F.; the less ductile product APM M276 shows an even greater superiority at temperatures above 500°F. In creep and stress rupture, these products again show superiority at 600°F. over all of the alloys produced by

TABLE 4
Fatigue Properties of Some Aluminum Alloys at Elevated Temperatures

		7075-T6	2024-T4	2014-T6	2618-T61	X2219-T6	M237	M257 (APM)	M276 (APM)
		FATIGUE STRENGTH, PSI							
75°F	10^4 CYCLES	55 000	56 000	52 000	---	---	---	---	---
	10^5 CYCLES	40 000	43 000	39 000	36 000	---	---	---	---
	10^6 CYCLES	29 000	31 000	30 000	31 000	---	---	---	---
	10^7 CYCLES	24 000	24 000	24 000	26 000	---	---	---	---
	10^8 CYCLES	22 000	21 000	19 000	21 000	---	---	---	---
300°F	10^5 CYCLES	27 500	---	24 000	---	---	---	---	---
	10^6 CYCLES	21 500	25 000	19 000	---	---	---	---	---
	10^7 CYCLES	16 500	20 000	14 500	---	---	---	---	---
400°F	10^5 CYCLES	20 000	24 000	22 000	22 000	21 000	23 000	11 500	14 500
	10^6 CYCLES	14 000	18 000	15 000	17 000	15 000	17 000	8 500	11 000
	10^7 CYCLES	10 000	13 500	9 500	13 000	11 000	13 500	7 000	9 500
500°F	10^5 CYCLES	16 500	24 000	19 500	22 000	---	---	14 000	18 000
	10^6 CYCLES	12 500	17 500	14 000	17 000	---	---	10 500	13 500
	10^7 CYCLES	9 000	12 000	9 500	12 000	---	---	7 500	10 000
	10^8 CYCLES	8 000	9 000	6 000	9 000	---	---	6 500	8 500
600°F	10^4 CYCLES	---	19 000	15 000	25 000	22 000	24 000	17 000	22 000
	10^5 CYCLES	---	15 500	12 000	19 000	17 000	19 000	13 000	17 000
	10^6 CYCLES	---	12 000	9 500	14 000	12 000	13 500	9 500	12 500
	10^7 CYCLES	---	9 500	7 000	9 500	8 000	9 500	6 500	9 000
	10^8 CYCLES	---	8 000	5 500	6 500	5 500	6 500	5 500	7 500

TABLE 5
Nominal Compositions of Cast Aluminum Alloys

	355	A355	142	XA140
Cu	1.3	1.4	4.0	8.0
Si	5.0	5.0	---	---
Mn	---	0.8	---	0.5
Mg	0.5	0.5	1.5	6.0
Ni	---	0.8	2.0	0.5

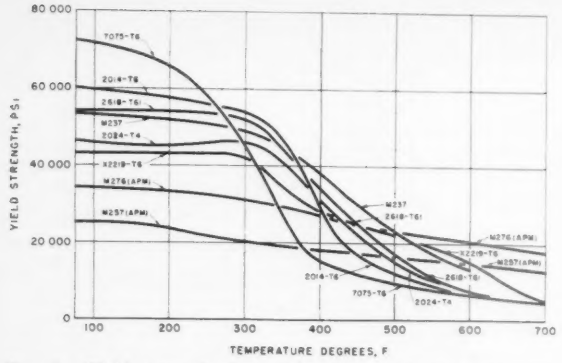

FIG. 1. Yield strength of wrought alloys at elevated temperatures after 100 hours at temperature.

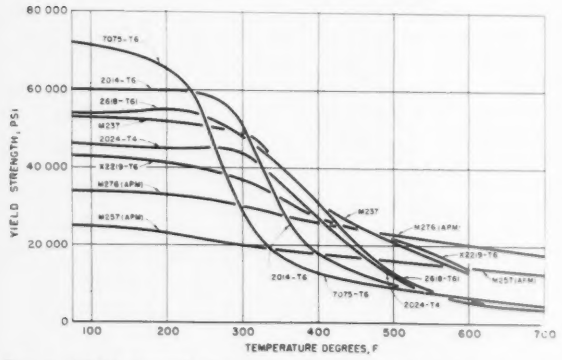

FIG. 2. Yield strength of wrought alloys at elevated temperatures after 1,000 hours at temperature.

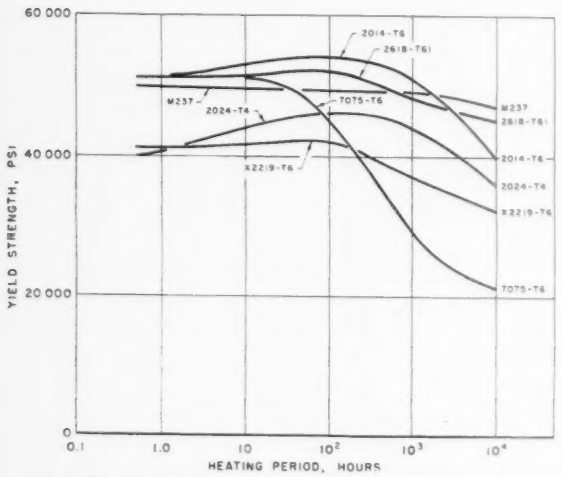

FIG. 3. Change of yield strength with time at 300°F.

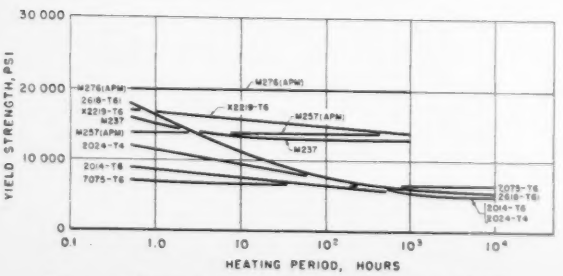

FIG. 4. Change of yield strength with time at 600°F.

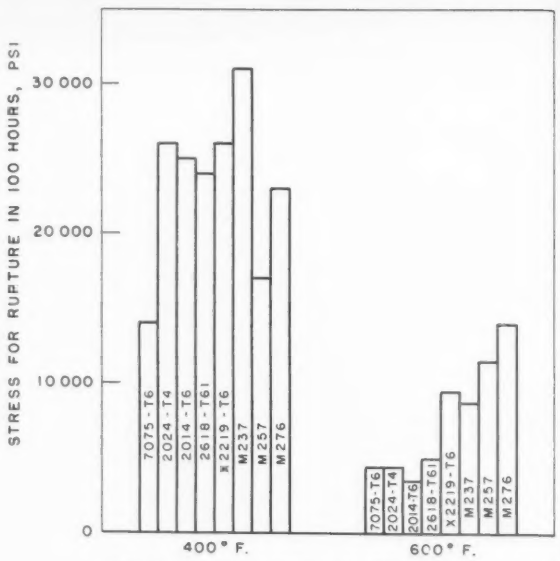

FIG. 5. Stress for rupture in 100 hours.

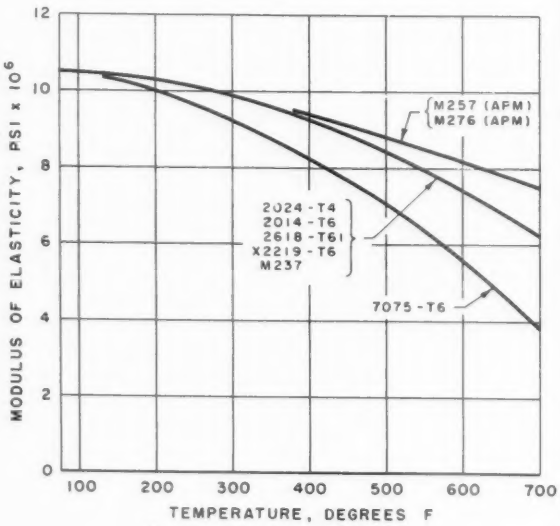

FIG. 6. Modulus of elasticity.

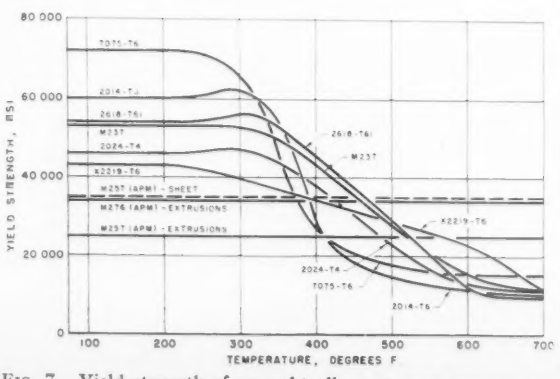

FIG. 7. Yield strength of wrought alloys at room temperature after 100 hours at temperature.

conventional processes. The fatigue characteristics of M257 are, in general, inferior to those of the conventional alloys even at 600°F. Alloy M276 shows improved fatigue characteristics over M257, and at 600°F. it is substantially equivalent to the best of the conventional alloys. It is of interest that there is much less difference in the fatigue strength of these APM products at 600°F. as compared with 400°F. than for conventional products. The APM product M257 has the highest thermal conductivity of the wrought materials discussed (Table 7).

The bar graph of Fig. 5, comparing the stress rupture strengths in 100 hours at 400° and 600°F., gives a good visual comparison of the wrought products just discussed. It emphasizes the superior stress rupture strength of M237 at 400°F. and of X2219-T6, M237, and the APM products M257 and M276 at 600°F.

The modulus of elasticity is an important design property for structural applications where buckling may occur. The modulus decreases with increasing temperature as is illustrated by Fig. 6. It was found possible to show the effect of temperature on the modulus of elasticity in a single curve for all of the air-frame alloys produced by conventional methods except 7075-T6. This alloy shows the greatest loss in modulus of elasticity, but this is of little importance since for other reasons it probably should not be used in service above about 250°F. The APM products M257 and M276 may also be illustrated by a single curve which is above that for the conventional alloys.

The casting alloys having the best properties for elevated temperature service have been described previously. Their normal composition is shown in Table 5. Their tensile properties at room temperature and when tested at temperatures up to 700°F. after one-half, 100, 1,000, and 10,000 hours at temperature are shown in Table 6. The marked superiority of the

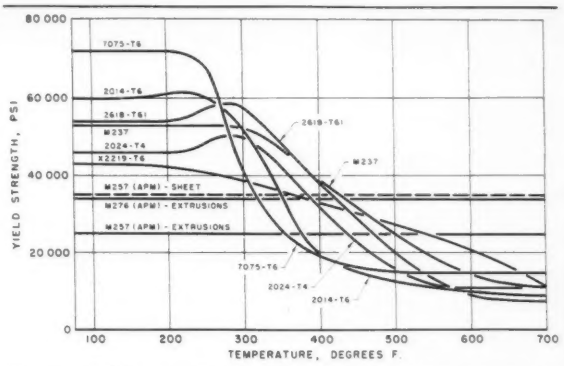

FIG. 8. Yield strength of wrought alloys at room temperature after 1,000 hours at temperature.

experimental alloy XA140-F in tensile and yield strengths is clearly illustrated. Although strictly comparable data on creep and stress rupture strengths are not available, it may be inferred from such tests as have been made that this alloy is superior to the other alloys at 400° but not at 600°F. The fatigue strength of the new alloy at 400° and 600°F. appears to be markedly superior to the other casting alloys.

To summarize the comparison of casting alloys, it may be said that the new alloy XA140-F is markedly superior to the other available alloys in tensile, tensile yield strength, and fatigue at temperatures of 400° and 600°F. At 400°F., it is superior in creep and stress rupture strength. The alloy has sand-casting characteristics somewhat superior to those of alloy 142. A tendency to hot cracking, however, may place limitations on the types of castings which may be made in permanent molds. It should be noted that, for applications where thermal conductivity is important, the lower thermal conductivity (Table 7) of this alloy should be given consideration.

TABLE 6
Tensile Properties of Some Sand Cast Alloys at Elevated Temperatures

Tensile Properties	355-T51			A355-T51			142-T77			XA140-F		
	Tensile Strength, PSI	Yield Strength, PSI	Elong. in 2 in., %	Tensile Strength, PSI	Yield Strength, PSI	Elong. in 2 in., %	Tensile Strength, PSI	Yield Strength, PSI	Elong. in 2 in., %	Tensile Strength, PSI	Yield Strength, PSI	Elong. in 2 in., %
Room Temperature	25 000	23 000	1.5	28 000	24 000	1.5	30 000	23 000	2.0	34 000	29 000	1.0
212°F - 1/2 HR	25 000	22 000	1.5	28 000	23 000	1.5	30 000	23 000	2.0	---	---	---
100 HR	25 000	22 000	2.0	27 000	23 000	1.5	30 000	23 000	2.0	---	---	---
1000 HR	25 000	22 000	2.0	27 000	23 000	1.5	30 000	23 000	2.0	---	---	---
10000 HR	25 000	22 000	2.0	27 000	23 000	1.5	30 000	23 000	2.0	---	---	---
300°F - 1/2 HR	26 000	21 000	2.0	26 000	21 000	1.5	29 000	22 000	2.0	---	---	---
100 HR	26 000	20 000	2.0	25 000	20 000	1.5	29 000	22 000	2.0	---	---	---
1000 HR	25 000	20 000	2.0	24 000	20 000	1.5	28 000	22 000	2.0	---	---	---
10000 HR	24 000	19 000	3.0	24 000	20 000	2.0	27 000	21 000	2.0	---	---	---
400°F - 1/2 HR	22 000	18 000	3.0	22 000	18 000	2.0	26 000	19 000	2.0	31 000	27 000	0.5
100 HR	20 000	16 000	3.0	19 000	15 000	3.0	23 000	17 000	2.0	37 000	30 000	0.5
1000 HR	17 000	14 000	5.0	18 000	13 000	3.0	22 000	16 000	2.0	35 000	28 000	1.0
10000 HR	14 000	10 000	8.0	17 000	12 000	4.0	20 000	15 000	3.0	---	---	---
500°F - 1/2 HR	15 000	14 000	5.0	17 000	14 000	4.0	21 000	16 000	2.0	---	---	---
100 HR	12 000	10 000	10.0	13 000	9 500	6.0	17 000	13 000	3.0	---	---	---
1000 HR	10 000	7 500	13.0	12 000	8 000	8.0	15 000	10 000	4.0	---	---	---
10000 HR	9 500	5 000	16.0	11 000	7 000	10.0	13 000	8 000	6.0	---	---	---
600°F - 1/2 HR	9 500	8 500	13.0	12 000	8 500	9.0	15 000	11 000	4.0	20 000	16 000	25.0
100 HR	7 000	5 000	24.0	9 000	6 000	9.0	11 000	7 500	4.0	20 000	14 000	25.0
1000 HR	6 000	4 000	30.0	8 500	5 500	9.0	9 500	5 500	12.0	19 000	14 000	25.0
10000 HR	6 000	3 000	36.0	7 500	5 000	10.0	8 000	4 000	20.0	---	---	---
700°F - 1/2 HR	5 500	4 500	25.0	7 000	5 000	10.0	9 000	6 000	8.0	13 000	7 500	48.0
100 HR	4 500	3 000	40.0	6 500	4 500	10.0	6 000	4 000	30.0	10 000	6 500	62.0
1000 HR	3 500	2 000	45.0	6 000	4 000	12.0	5 000	3 500	35.0	---	---	---
10000 HR	3 500	2 000	50.0	6 000	4 000	15.0	5 000	3 000	40.0	---	---	---

TABLE 7
Thermal Conductivity of Some Aluminum Alloys

ALLOY	THERMAL CONDUCTIVITY AT 25°F (77°F), CGS UNITS
WROUGHT	
7075-T6	0.29
2024-T4	0.29
2014-T6	0.37
2618-T61	0.37
X2219-T6	0.32
M237	0.32
M257 (APM)	0.46
M276 (APM)	0.37
SAND CAST	
355-T51	0.40
A355-T51	0.40
142-T77	0.36
XA140-F	0.23

RESISTANCE TO CORROSION

The resistance to corrosion of X2219 and M237 alloys has been evaluated in a preliminary way by tests of 0.064-in. thick sheet alternately immersed in a 3.5 per cent sodium chloride solution (10 min. immersion in each hour) for periods up to 26 weeks. This test included unstressed specimens, specimens stressed to three-quarters of the yield strength, and specimens preformed and then highly stressed. There were no stress corrosion failures and little acceleration of loss in tensile strength in the stressed specimens. The alclad specimens of both alloys showed no loss in tensile strength either stressed or unstressed in this period of exposure.

In this test, these new alloys showed a somewhat higher loss in tensile strength in the unstressed condition than the 2024-T3 specimens included for comparison, but the losses of the stressed specimens were somewhat lower than those of 2024-T3. In a single comparison on 1/8-in. diameter specimens cut in all three directions from 2 by 3 in. forged bar and stressed to three-quarters of the yield strength, none have cracked after 12 weeks in the alternate immersion test previously described.

From these limited tests, it is estimated that the resistance to corrosion of these two new alloys would be of the same order as that of 2024.

The resistance to corrosion of the APM products is of a high order, substantially equivalent to that of commercially pure aluminum. These products have shown no evidence of susceptibility to stress corrosion cracking.

Of the casting alloys, the resistance to corrosion of alloys 355 and A355 is the highest of the group with alloy 142 being lower; alloy XA140, judging from its chemical composition, would have a resistance to corrosion comparable with or slightly lower than alloy 142.

CONCLUSION

The author has presented data on one new casting alloy, two new wrought alloys, and two APM products, as well as on a forging alloy which has not been used for air-frame structures. It has been indicated that the high-strength aluminum-zinc-magnesium-copper alloys as typified by 7075-T6 are not efficient for air-frame structures at temperatures above 250°F. The standard air-frame alloys, 2024 and 2014, appear to be appropriate for temperatures in the range of 250° to 350°F., alloy 2014-T6 having a small advantage in tensile, stress rupture, and creep strengths and 2024-T4 in fatigue strength. Within this same range of temperature and up to about 450°F., alloy 2618-T61 deserves consideration, but its possible choice depends on the specific governing property and the time. In the temperature range 350° to 500°F., the experimental alloy M237 should be considered where strength, creep, stress rupture, and fatigue properties are important. From 500° to 650°F., the alloy X2219-T6 has some important advantages in creep and stress rupture. Above 600°F., the APM products show marked superiority over any of the conventionally produced alloys.

It is important to both the aircraft industry and the aluminum industry that the new alloys mentioned should be evaluated promptly to determine whether or not their properties justify their commercial production for use for air-frame structures. The new casting alloy XA140 is at present available only for experimental use. Alloy 2618 is now available as forgings only. Are its elevated temperature properties such as to require it in the form of sheet, alclad sheet, plate, and extrusions? Alloy X2219 is also available for experimental use in the form of extrusions and forgings. It remains to be determined whether there will be a substantial requirement for this alloy in the form of sheet, plate, and alclad sheet. Alloy M237 is still further from commercialization, but the aluminum industry would like to know whether its elevated temperature characteristics would justify its development for sheet, alclad plate, extrusions, and possibly forgings.

The aluminum industry is willing and anxious to do its share in developing these new products, but it needs the guidance of the aircraft industry. The introduction of a new alloy or product for aircraft service requires an extensive program of evaluation and development. Neither the aircraft nor the aluminum industry can afford this effort unless there seems to be a reasonable chance that the new products will represent a significant improvement over the standard air-frame products now available.

(*Continued on page 57*)

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Inertial Navigation

A method for the determination of position by measurement of acceleration and vehicle velocity which —unlike the methods of celestial navigation or dead reckoning—is not subject to errors induced by outside disturbances.

AN IMPORTANT CHANGE is now taking place in the science and art of navigation, a field in which past advances have often had significant influence. One recalls such events as the invention of the temperature-compensated chronometer which, by giving England an advantage in the navigation art in the eighteenth century, was a significant factor in the attainment of British maritime supremacy; one recalls, also, the perfection of the gyro compass some 40 years ago.

Inertial navigation is passing from the realm of a theoretical possibility to a practical reality. The new science and art is totally different from previous methods. It depends upon sensing and integrating vehicle accelerations to find position.

At the present time, inertial navigation is being applied almost exclusively to military problems. Because of the necessary security restrictions, only relatively few persons are aware of the details of the systems being developed. The basic principles, however, have been known to the scientific world for many years and cannot be considered classified. This brief account is intended to outline what inertial navigation is, the principles upon which it works, and its relationship to older navigational forms.

Navigation is the science of determining position, especially of a moving vehicle. It is closely allied with cartography, the science of determining the location of a fixed point and recording it on a map.

The most accurate method of determining position is based upon celestial observations. The astronomical latitude and longitude of a fixed point can be measured with an extremely high degree of precision. Accuracy is determined by the precision of measuring time and the angular position of stars with respect to the direction along the local gravitational vertical. Using modern equipment, accuracy considerably better than 1 sec. of arc (100 ft. on the surface of the earth) can be achieved.

The same method is used for navigating ships, except that a new important source of error is introduced. Movement of the ship makes it impossible to determine accurately the direction of the local vertical by using bubble levels or equivalent instruments satisfactory for the fixed-point problem. All such instruments will be equally sensitive to the acceleration of gravity and to the acceleration of the ship. At sea, the horizon itself affords a much better reference and is normally used in navigation. In this way, accuracy of the order of 1 min. of arc (1 nautical mile on the surface of the earth) can be achieved, but nothing approaching the accuracy with which fixed points can be located.

When the same method is applied to airplanes, even greater errors are introduced. Because of clouds and mountains, the horizon no longer provides a satisfactory vertical reference and a bubble sextant is normally used. As in the case on the moving ship, however, this instrument cannot distinguish between the acceleration of gravity and vehicle accelerations. Errors are introduced which become prohibitive on modern high-speed airplanes or missiles. For example, consider the case where an airplane is flying at Mach 1 on a path which the pilot thinks is straight but which is slightly curved with a radius of curvature of 1,000 miles. The centrifugal force associated with even this very slight curve would introduce an error of approximately 20 miles.

Other disadvantages of celestial navigation when applied to high-speed aircraft are the restrictions on cloud cover overhead and the time required for the navigator to complete his calculations. At modern speeds the airplane could be in a different country by the time position was determined. Some attempts were made at mechanizing these calculations to produce automatic celestial navigation, but the basic limitations on accuracy indicated that there was little point in further refinements of this method.

Another type of navigation employed in the past is dead reckoning. First position is precisely determined at a known point; measurements are then made to determine velocity. In an airplane, velocity can be determined by using an air-speed indicator and a compass. A continuous plot of position can then be obtained by multiplying velocity and time. (If velocity is not a constant, position is determined by the time integral of velocity.) Unfortunately, the measurements of both magnitude and direction are subject to

* Staff Specialist.
† Research Group Leader.

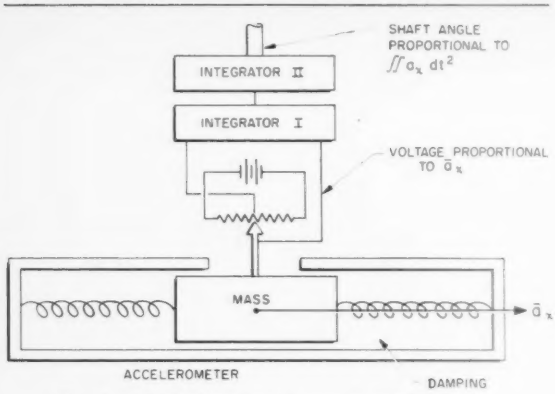


FIG. 1. Navigational accelerometer and integrator.

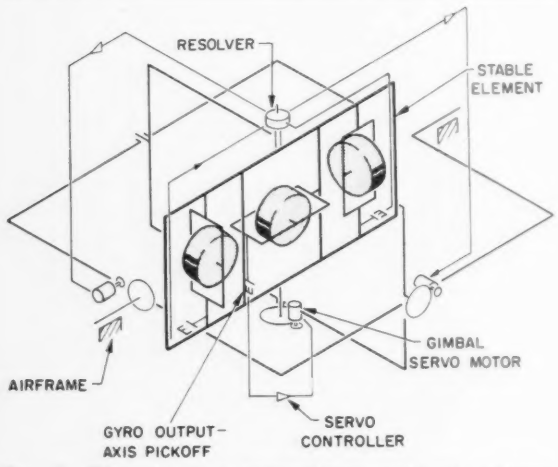


FIG. 2. Elements of a gyroscopically stabilized platform.

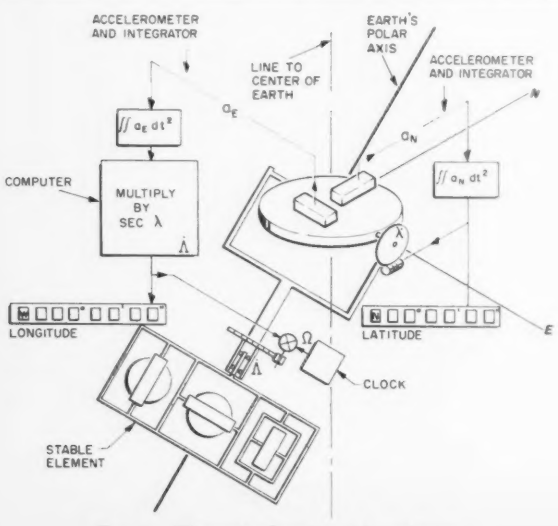


FIG. 3. Elements of an inertial navigator.

considerable uncertainty. Dead-reckoning navigation will, in general, have errors which are a significant percentage of the range traveled since the last known point. While useful, such information does not satisfy precise navigational requirements.

Further refinements of dead reckoning are complicated by the fact that extremely few basic physical phenomena are functions of velocity. The accuracy of an air-speed indicator, being based upon numerous empirical relationships, is definitely limited, and, more important, speed with respect to the air mass instead of the ground is measured. Unknown wind velocities, therefore, introduce errors which cannot be corrected by further instrument refinement. Other techniques for measuring velocity are known but appear to have limited potential accuracy.

The fundamental law of inertia upon which all mechanics is based involves acceleration, not velocity. Newton's Second Law states that force is equal to time rate of change of momentum, without approximation or correction for any effect. The accuracy of this law in the velocity range of interest in navigation has been experimentally verified to a high degree of precision. Here, then, is a fundamental effect, true without approximation, upon which a navigation system can be based which will not have any inherent accuracy limitations.

In some ways intertial navigation is similar to dead reckoning. Acceleration is measured with some type of instrument. Steps are taken to ensure that the only acceleration "seen" by the instruments is that due to change of vehicle velocity. Velocity is obtained as the time integral of acceleration. Knowing velocity, position can be determined as in a conventional dead-reckoning system, by a second step of integration. Note, however, that acceleration with respect to inertial space is sensed. Therefore, no corrections for wind velocity, airplane "crab angle," or any of the other sources of error inherent in dead reckoning appear. Unlike any previously used scheme for air-borne navigation, if the instruments are perfect, there is no error whatever, regardless of wind, airplane maneuvers, magnetic storms, enemy jamming, or any other outside disturbance.

An inertial navigator will then typically include the equivalent of a pair of translational accelerometers, disposed at right angles so that one senses accelerations along a North-South line and the other East-West, or in some other convenient coordinate system. Provided that the accelerometers can be made to "see" only changes of vehicle motion and not gravity or other disturbing accelerations, the outputs, doubly integrated with respect to time, can be interpreted as distance traveled. Or, by dividing by a radius, the outputs can be interpreted as angles—latitude angle, for example.

From here on the discussion will be confined to a latitude-longitude system, and more particularly a geocentric latitude-longitude system (λ, Λ). This is based on use of a line to the center of the earth, rather

than direction of a plumb line. As will be seen, these are not quite identical.

Fig. 1 is a diagrammatic representation of the accelerometer and pair of integrators.

In order to ensure that the accelerometers are not subject to undeterminable components of gravity, they are mounted on a stable element—a device which keeps some predetermined spatial orientation irrespective of changes of attitude and heading of the vehicle. The stable element (Fig. 2) is afforded by a set of gyroscopes in a frame which is gimbal-mounted for three degrees of freedom relative to the air frame. The stable element, together with the gimbals and gimbal servosystems, is called a stable platform.

The well-known property of gyroscopes of preserving angular fixity in space is utilized (to the extent that disturbing torques on the gyroscopes can be eliminated). Each gyroscope may be of the single-degree-of-freedom type, as sketched. Here, torque about the input (platform gimbal) axis causes no deflection about that axis. Precession takes place about the output (rotor support) axis. A sensitive pickoff detects such precession and calls up an opposing input axis torque via a servocontroller and a servomotor on the gimbals. In general, resolution of the gyroscope signals is required, since the stable element may assume any orientation relative to the outer gimbal axes.

As in celestial navigation, the equivalent of a clock is needed. This can be provided as a gear drive between the gyroscope assembly and the accelerometers to rotate the latter relative to the former at the rate corresponding to the angular velocity of the earth, Ω, which is 15 deg./hour.

A computer is needed to perform certain trigonometric operations to convert the integrated accelerometer outputs into data applicable to some particular coordinate system and also to make corrections for certain disturbing accelerations.

The elements of the inertial navigator are, thus, typically (1) accelerometers with double integrators, (2) gyroscopically stabilized platform, (3) clock, and (4) computer.

In Fig. 3 these are shown assembled into a system. The accelerometers are located on an equatorial mount, the outer axis of which is disposed along the earth's polar axis, so that by proper drives the accelerometers can be kept substantially level (whatever orientation the gyroscope assembly may assume) and hence not "see" g. Symbols Ω, $\dot{\Lambda}$, and $\dot{\lambda}$ refer to angular velocities of the several shafts.

The latitude channel is quite straightforward. The output of the N-S accelerometer is doubly integrated and is then supplied as a gear drive on the E-W trunnion. Assuming proper choice of scale factors and no change in altitude—i.e., in radius from the center of the earth—the table will be angularly accelerated at the same value as the angular acceleration of the vehicle about the center of the earth. The table angular velocity will be equal to vehicle angular velocity, and total angle to latitude.

This functioning is illustrated in Fig. 4 which shows the latitude channel only. The equipment is supposed to be set at zero at the equator. As it moves north along a meridian, the accelerometer table rotates so as to keep aligned with the center of the earth. Cross-level is maintained by the clock drive which "unwinds" earth rotation.

The longitude channel is identical except for the fact that the linear distance traveled on the surface of the earth corresponding to a given change in longitude angle depends on latitude. It is therefore necessary to multiply the output shaft velocity of the E-W accelerometer integrator by the secant of the latitude angle, before application to the mount drive. There it is added algebraically to the clock signal.

There can now be considered the oscillatory properties of an inertial navigator. It has such properties, and they are indeed essential to its successful operation.

It might be supposed that any constant acceleration error would cause a position error build-up in accordance with the relation $s = (1/2)\,at^2$. It is easy to see that if such were the case, even with instruments of remarkable degree of perfection, intolerable position

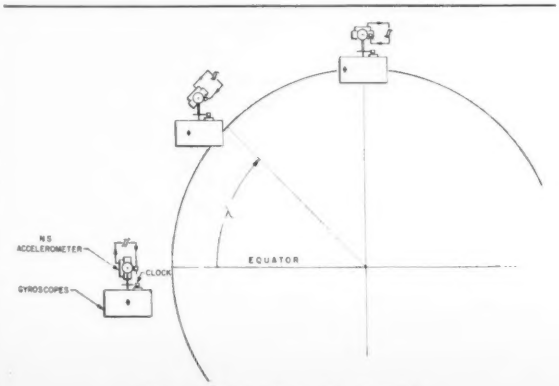


FIG. 4. Operation of λ-channel.

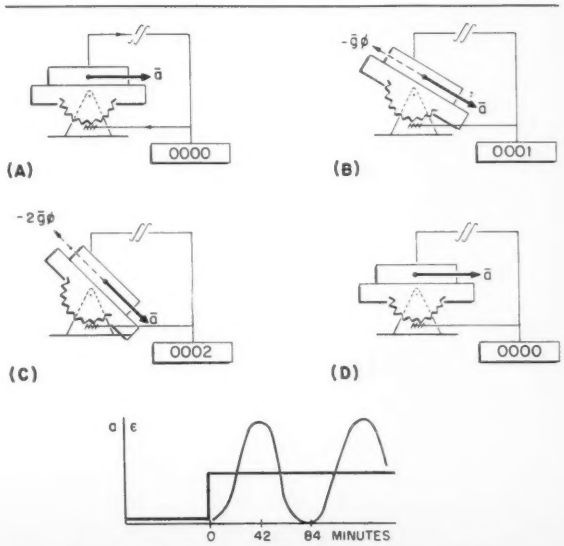


FIG. 5. Oscillatory nature of acceleration error.

errors would result. Actually, an acceleration error results in a position error which is bounded—i.e., does not increase (in average value) with time. This fortunate circumstance comes about only because the earth has a finite radius. Inertial navigation over an infinite flat earth would be much more difficult.

Looking at the latitude channel again, with the vehicle at rest, consider what happens if a steady acceleration error is introduced, as by a slight permanent change in tension on the spring (Fig. 5). The device "thinks" that the vehicle is accelerating, and the double integrator gives a spurious indication of change of latitude, at the same time tilting the table in the same direction. This tilt causes the accelerometer to sense a component of gravity. At some angle of deflection, this component of g will balance the spurious acceleration, and the signal to the integrator becomes zero. The device "overshoots," however; the integrator keeps running, tilting the table ahead, until enough component of g has been developed to bring the drive shaft to zero speed. The cycle then reverses and repeats itself—acceleration, velocity, and angle all being 90° out of phase—giving an error plot as sketched in Fig. 5.

The combination of accelerometer, integrator, and feedback acts, behaves in fact, exactly like a long-period pendulum. An acceleration disturbance results in an *oscillation*, not a cumulative integrated error. The period of the pendulum may be calculated as follows.

Scale factors have been chosen so that the angular acceleration $\ddot{\phi}$ of the table will be equal to $\ddot{\theta}$, the angular acceleration of the vehicle about the center of the earth. Since $a = R\ddot{\theta}$, this means that

$$\ddot{\phi} = \ddot{\theta} = a/R = ka$$

where $k = 1/R$.

If, then, the assembly is deflected through an angle ϕ, the accelerometer senses a component of g, $a = -g\phi$. Thus,

$$\ddot{\phi} = -kg\phi = -g\phi/R$$

Comparing with the equation for a simple oscillator,

$$\ddot{\phi} + \omega^2\phi = 0$$

it is seen that

$$\omega^2 = g/R$$

or

$$T = 2\pi/\omega = 2\pi\sqrt{R/g}$$

Putting in values for R and g at the earth's surface, $T = 84$ min., approximately.

Acceleration errors are of an oscillatory nature even for pendulous systems of period other than 84 min. For a system "tuned" to the 84-min. period, its angular acceleration $\ddot{\phi}$ will be equal to the angular acceleration $\ddot{\theta}$ of the vehicle about the center of the earth, whereas with shorter or longer periods this will not be the case. For example, in the bubble sextant the period is extremely short and $\ddot{\phi}$ will be much greater than $\ddot{\theta}$. In the inertial navigator we have artificially lengthened the pendulum period to obtain the required relation $\ddot{\phi} = \ddot{\theta}$.

This apparatus described so far would constitute a complete inertial navigator except for the existence of certain "phantom accelerations" which are a result of the earth's rotational velocity.

A horizontal acceleration component exists, in the meridian, which is the vector sum of centripetal acceleration and the horizontal component of g due to the oblateness of the earth. The spurious acceleration is proportional to $\Omega^2 \sin 2\lambda$, being maximum at about $\lambda = 45°$, where the deviation of the plumb-line vertical from the line to the center of the earth is about 11 min. of arc. Compensation can be by computation of bias voltage for the N-S accelerometer proportional to $\Omega^2 \sin 2\lambda$.

The acceleration of Coriolis can also introduce error. For flight at constant altitude only the horizontal component $a_c = 2\,\Omega V \sin\lambda$, where V is ground velocity, is important.

The acceleration of Coriolis is an elusive thing to get a "feel" for. It exists because of the fact that we are doing our navigation on a rotating base. Consider an airplane flying along a meridian near the pole. Now, while this is a "straight" course relative to the earth, it is a deflected one in space. The airplane traveling at constant ground velocity V, is continuously changing the magnitude of its tangential velocity *in space*. It is also continuously changing the direction of the vector $\bar{V}$ *in space*. The two effects, equal in magnitude, add to give the $2\Omega V$ term. In compensating, the components of V may be obtained by a single integration of the accelerometer outputs, multiplied by $2\Omega \sin\lambda$ and applied as bias voltages.

In navigators for vehicles having a wide range of vertical velocity and height above the earth, other corrections must be made; these are unimportant, however, to an understanding of the principles.

Since the basic law underlying inertial navigation has been known since Newton and since the method offers many operational advantages over other methods, one may wonder why it has not been used previously. The answer may be summarized somewhat as follows. Other navigational methods give useful answers with moderately precise instruments but have inherent limitations beyond which further refinements in components no longer help. Inertial navigation has no such limitation, but extremely precise instruments are required before even moderately acceptable performance can be achieved. Only in recent years have technical arts been advanced to a degree where developing such instruments appeared to be in the realm of possibility. Inertial navigation is based on force balancing and measurement operations which must be carried out with a degree of precision quite comparable with that used in establishing basic standards in the great physical laboratories. And it is necessary

(*Continued on page 57*)

A description of a means of making inert the various ignition sources within the jet engine, principally by the use of water cooling.

Crash-Fire Research with Jet Aircraft*

I. Irving Pinkel†
Lewis Flight Propulsion Laboratory, NACA

RESEARCH ON THE ORIGIN of crash fires, conducted by the NACA from 1949 to 1953, covered airplanes powered with reciprocating engines.[1, 2] This report reviews the full-scale research with jet aircraft that followed the work with reciprocating-engine aircraft.

The work on the origin of crash fires includes a full-scale crash phase along with supporting laboratory studies. In the full-scale phase, fully instrumented aircraft are accelerated from rest under their own power and guided into a crash barrier where the damage imposed is typical of take-off or landing accidents in which large quantities of fuel spill. This accident is studied because it occurs at low airplane speed and the chance is good for passenger survival of the crash impact. (Motion pictures show the airplane accelerating along a 1,700-ft. runway, where it attains a speed of 100 m.p.h. before crashing into a barrier at the end of the runway. In this instance, the airplane involved is a cargo type powered with reciprocating engines.)

The work with the reciprocating-engine aircraft showed how the airplane combustibles—oil, fuel, and hydraulic fluid—spill in a crash, how the movement of the spilled combustibles to the ignition sources start the fire, and when and where these ignition sources are likely to appear. Much of what was learned applies to turbojet aircraft. However, there are some additional considerations, chief among them being that the turbojet has no propeller to strike the ground and bring the engine to rest. Therefore, the engine continues to run after crash and draw large volumes of air into the engine inlet. Crash-spilled combustibles can be sucked into the engine inlet with the air and ignite explosively within the engine.

This explosive ignition was studied in detail with a turbojet on the test stand. (Motion pictures show the flames that issue from the test stand engine following the ignition of fuel sucked into the operating engine with the intake air. Scraping of the compressor blades on the compressor case produces flakes of magnesium burning in the flaming fuel. Flames also appeared at the engine tailpipe. The flames issuing from the engine inlet and tailpipe can reach fuel spilled around the crashed airplane and set the airplane on fire.

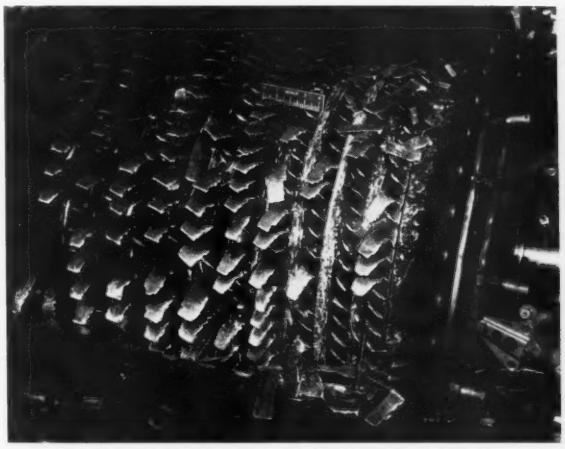


FIG. 1. Damage to compressor rotor.

Loss of the compressor and other engine components sometimes accompanies this explosion. The compressor damage produced by the explosion just described is shown in Fig. 1. Many of the missing compressor blades piled up at the inlet screen.

The test-stand studies showed that the combustibles sucked into the engine can be ignited by the continuous flame in the engine combustors or by the hot metal of the engine interior for a short time after the combustor flame is extinguished.

To check these results in actual crash, turbojets were pylon-mounted to the wings of a cargo airplane—from which the reciprocating engines were removed—to simulate one type of the jet bomber. The operating jet engine powered the airplane into the crash barrier. The airplane carried 1,000 gal. of JP-4 fuel. Arrangements were made to stop the fuel flow to the engines at the moment of crash impact. The flame in the engine

Presented at the Aircraft Safety Design and Accidents Session, CAI-IAS International Meeting, Ottawa, Canada, Nov. 3–4, 1955.

* Experience has shown that a sequence of still pictures is an inadequate substitute for motion pictures. For this reason, this draft of the discussion does not include sequences of still pictures when the text calls for motion pictures. Instead, a summary of what appears in the motion pictures is given at the appropriate times.

† Associate Chief, Physics Division.

combustor was thus extinguished, leaving only the hot metal of the engine as the ignition source.

(Motion pictures show the passage of the simulated jet bomber through the crash barrier, where damage is imposed similar to that shown for the cargo airplane.) After the airplane passes through the barrier, fuel spilling from the damaged wing tanks is sucked into the engine, where it ignites on the hot metal of the engine interior. Flames issuing from the inlet and tailpipe ignite the fuel spilling from the wing and set the major fire.

With the ignition of crash-spilled combustibles by the hot engine parts demonstrated on the test stand and in full-scale crash, the search for these ignition sources was made. The search began with a measurement of the metal temperatures in the operating engine. Some characteristic engine component temperatures obtained are shown along the ordinate in Fig. 2. The turbine blades and the hottest parts of the transition liner run about 1,300° and 1,700°F., respectively. The turbine wheel, which is not in the main gas stream, heats by conduction from the rim, and its hottest parts are about 900°F. When the combustor fuel flow is cut off (at zero on the abscissa scale), the temperature of the engine elements in the now relatively cool engine air stream decreases rapidly. The temperature of the turbine blades falls to 800°F. in 5 sec., and the transition liner cools from 1,700° to 800°F. in 20 sec. However, the turbine wheel is not in direct contact with the main engine flow and hardly cools at all. In fact, parts of the turbine wheel are hot enough to ignite JP-4 fuel 30 min. after engine shutdown. In general, this temperature survey of the engine showed that all the engine metal downstream of the combustor is above the ignition temperature of JP-4 for varying periods of time following combustor fuel shutoff.

When the problem of what may be done to reduce the likelihood of crash fire is considered, it is evident at once that provision should be made to shut off the fuel flow to the engine combustor when crash occurs. In this way, the continuous flame in the combustor is eliminated as a positive ignition source. In the remainder of this discussion, it is assumed that the engine is equipped with a crash-sensitive fuel valve that cuts off the engine fuel flow. However, in view of the engine metal temperatures just described, the question arises: Are all of the hot engine components downstream of the combustor potential ignition sources in a crash? If this should prove to be so, then fire prevention in crash would require that a formidable weight of fire-extinguishing agent be mixed with all the air entering the engine. The extinguishing agent would have to be discharged into the engine at the moment of crash impact and continue to flow until the engine rotor coasts to rest.

In the present approach to reduction of crash-fire hazards, cognizance is taken of the fact that ignition of hydrocarbon atmospheres by hot surfaces is not instantaneous. The contact time between the combustible atmosphere and the hot wall required for ignition varies with wall temperature and atmospheric pressure in the manner shown in Fig. 3. The required contact time increases with decreasing wall temperature and decreases with increasing pressure. Since the gas pressure is higher in the combustor than elsewhere in the engine, contact time and wall temperature required for ignition are lowest here.

Because of the high gas velocity through the engine, the combustible atmosphere flowing through the engine has insufficient contact time with the bulk of the hot metal surfaces for ignition. However, there are a few zones within the engine where sufficient contact time is possible. These zones are shown on the engine in Fig. 4. Moving in the direction of flow, the first ignition zone is located at the combustor dome. Here a portion of the engine air is caused to recirculate by design and form a zone of reduced translational speed. Also, in this region, residual flames linger briefly as the fuel flow is shutting down after crash impact. Crash-spilled combustibles sucked into the engine inlet arrive here under pressure and well mixed with the air by the compressor.

Whereas the gas velocity along the inside wall of the transition liner is too high for ignition, the small amount of gas diverted from the combustor flows along the outside surface of the transition liner with sufficient contact time to ignite. The outside wall of the transition liner is the second ignition zone.

The air drawn from the compressor for cooling the turbine wheel can bring with it the combustibles sucked into the engine inlet. A relatively long residence time is available, and ignition is likely. Also, this combustible mixture may enter the vent holes in the base of the internal tail cone and ignite on the hot walls of the quiescent interior. These vent holes are shown in Fig. 5. Notice the damage to the tail-cone diaphragm produced by an internal ignition of the type just discussed.

These four ignition zones are all that were found within the engine. Fortunately, these zones are small, and it appeared feasible to cool them by water streams. This method was tried successfully in the test-stand engine. The water system for the combustor-liner dome shown in Fig. 6 is a typical example of the plumbing required. Mounted concentric with the fuel nozzle is a toroidal water duct containing spray holes for injecting water into the combustion zone and holes for spraying water over the combustor liner. A total of 2 gal. of water, discharged in 4 sec., is used for all combustors of a J47 engine. All the transition liners are cooled similarly with simple plumbing by 1 gal. of water; 1 gal. of cooling water for each face of the turbine wheel is delivered to the hub and spread centrifugally by wheel rotation. A small water spray into the interior of the inner tail cone generates sufficient steam to maintain an inert atmosphere. Since oil or fuel spilled on the outside wall of the tailpipe ignites quite readily, 2 gal. of water are used here.

The cooling of the turbine wheel, provided by the water, is shown by the data in Fig. 7. This figure gives

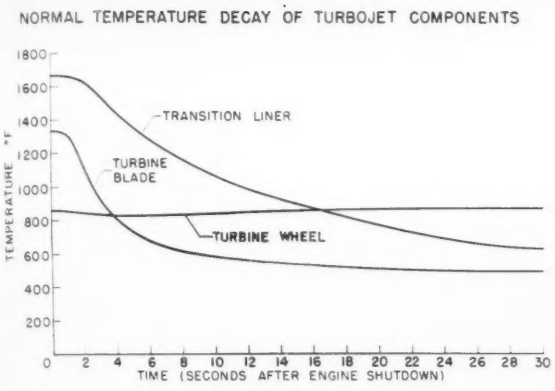


FIG. 2.

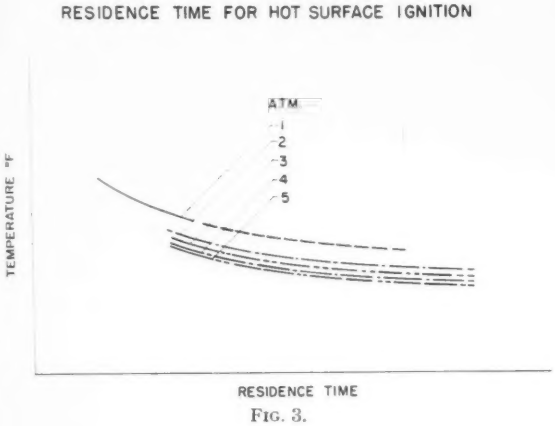


FIG. 3.

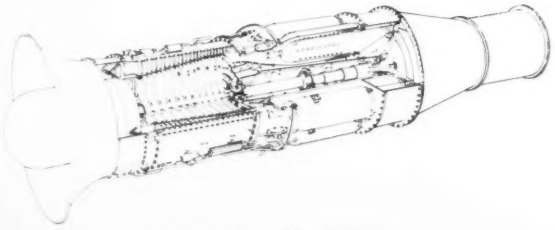


FIG. 4. Turbojet cutaway.

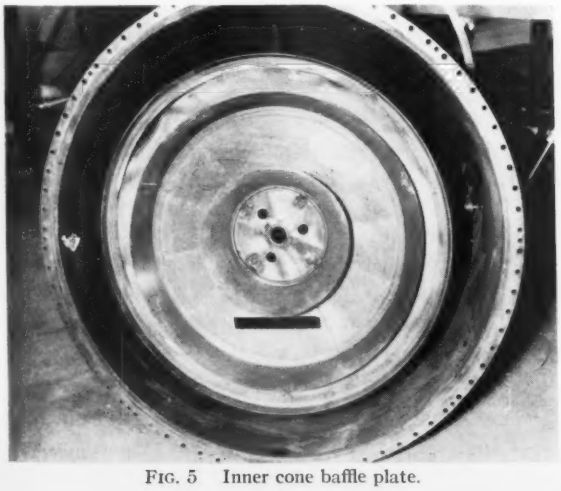


FIG. 5 Inner cone baffle plate.

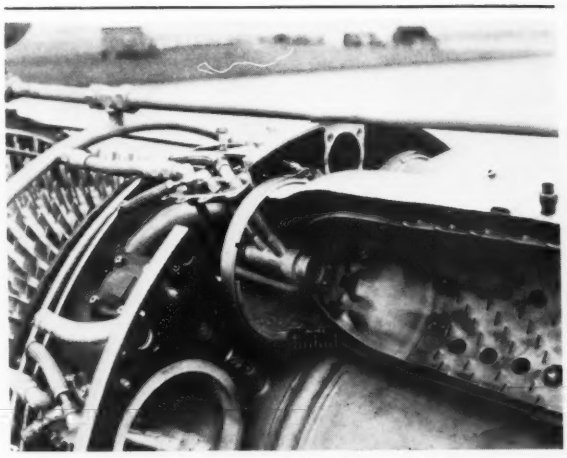


FIG. 6. Combustion chamber dome water nozzle.

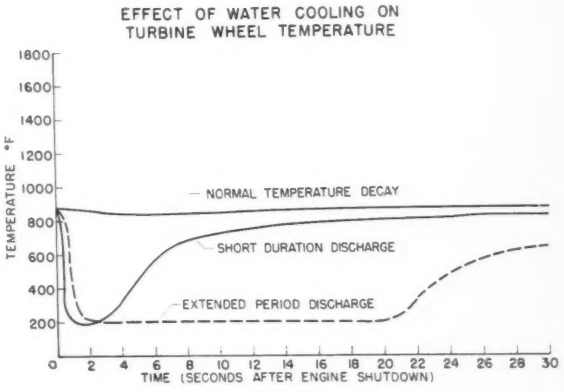


FIG. 7.

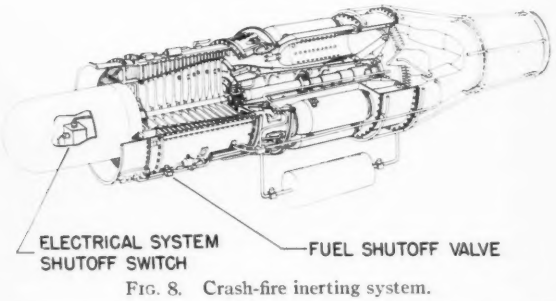


FIG. 8. Crash-fire inerting system.

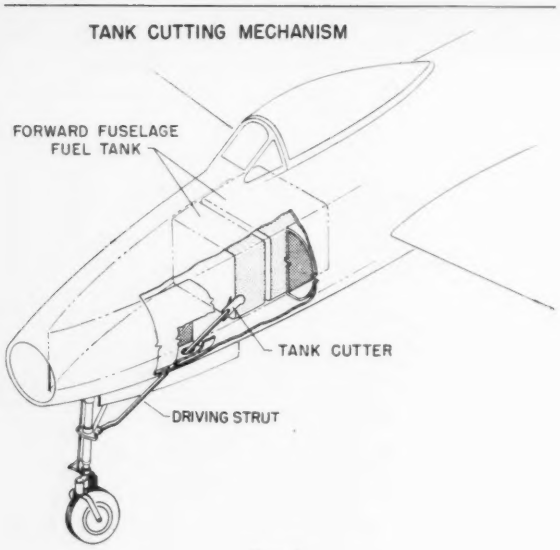


FIG. 9.

the temperature at the surface of the hottest part of the wheel. The turbine wheel is selected to illustrate the water cooling because its large heat capacity makes it the most difficult engine element to cool. At zero time, the fuel to the engine combustor is turned off and the water spray comes on. Notice that the turbine wheel cools quite rapidly at first to temperatures below 600°F., the lowest ignition temperature for JP-4 obtained with the engine. While the wheel cools to safe temperatures, it is shrouded with steam that prevents ignition. Once the water is discharged, in 4 secs., the surface of the wheel reheats above safe temperatures by conduction from the hot wheel interior. A secondary water flow of $^1/_2$-gal. spread over 30 sec. prevents this reheat and gives the safe cooling curve (dashed).

In crash study of this use of water for preventing crash fire, the water is carried under gas pressure and discharged at the moment of crash impact. The complete crash-fire safety system (shown schematically in Fig. 8) also includes the combustor fuel shutoff mentioned earlier and an electrical system disconnect for cutting off the battery and generator circuits, when crash occurs. Earlier work with reciprocating-engine aircraft showed the need for this disconnect to avoid hot wires and electric arcs that can ignite the airplane combustibles.

In six crashes in which this protection system was used, no fire occurred. Four of these airplanes were cargo airplanes with pylon-mounted jet engines, and two were F-84 airplanes with engines submerged in the fuselage. Four of these six crashes were of special interest.

In the first of these four crashes the cargo airplane ground-looped after passing through the crash barrier and was heavily damaged. (Slow-motion pictures show the cargo airplane with pod-mounted jet engines carrying the protection system just described.) Upon impact with the crash barrier, the airplane fitted with the crash-fire protection system (Fig. 8) loses a wing, and fuel mist develops rapidly. Then the airplane ground-loops. Water vapor pours from the tailpipe as a result of water evaporation within the engine. Fuselage collapse brings the high wing and its engine to ground level, and fuel spilling from the wing pours over the engine. A pool of fuel observed at the engine inlet lips after the engine rotation stopped represents part of the fuel that entered the engine after crash.

The engine bearing on the ground suggested the possibility that pylon-mounted engines might tear free in crash. For this reason, arrangements were made in the next crash to rip the engine from the wing. The water reservoirs of the protection system were fastened to the engine to provide fire protection after engine separation from the wing. (Slow-motion pictures show the cargo airplane with protected jet engines, one of which is arranged to be ripped free from the wing when the airplane passes through the crash barrier.) In crash, the engine tears free and tumbles in the fuel mist spreading behind the wing. The water cloud issuing from the tailpipe indicates that the protection system is functioning. No fire occurs.

The crash-fire inerting system for the F-84 engines submerged in the fuselage was a little different from the system for the pod nacelles. In order to ensure entry of the fuel into the engine inlet when this airplane is crashed, the apparatus shown in Fig. 9 was used to rip open the fuselage fuel tank. A bar fastened to the F-84 nose gear pointed at the wall of the 100-gal. fuel tank in the engine inlet. Upon crash impact, the bar attached to the nose gear pierces the fuel tank wall and releases the fuel into the engine inlet. In the crash, the airplane carried a full load of JP-4 fuel and was protected like the cargo airplanes. (Slow-motion pictures show the F-84 crash; engine protected as described.) The crash arrangements are about the same for the F-84's as for the cargo airplanes. The fuel mist from the broken wing tanks shroud the area. Some of the vapor from the tailpipe is provided by the fuel that passes through the engine from the damaged inlet tanks. The water evaporating within the engine contributes a large part of the vapors formed. Inspection of the engine taken from the airplane after crash showed the tell-tale dye stains left by the red-dyed fuel in the compressor.

To check whether or not fire would occur if no protection were provided, this crash was repeated without the inerting system. (Slow-motion pictures show the F-84 crash; no crash-fire protection.) A succession of flames issue from the tailpipe after the airplane strikes the ground beyond the barrier.

A second crash of the F-84 airplane with protection system indicated again that the system is effective. (Normal-speed motion pictures show the F-84 crash; crash-fire protection.) Complete wetting of the airplane by the red-dyed fuel was observed.

These crash results with protected aircraft confirm the fact that the ignition sources within the engine that appear in crash were identified in the engine test-stand

studies. These results also show that the use of water as described is one way of inerting these ignition zones.

Since there appears to be no way to cope with the fire hazard created by hot parts shed when an engine breaks up in a crash, no study of this phase of the problem will be made. It is recognized without further study that fire is likely should some of the engine parts scattered by a disintegrating engine land in fuel-wetted zones around the crashed airplane. Some comfort may be drawn from the fact that, although the engine struck the ground a hard blow in five crashes, the hot parts of the engine remained in place.

Engine deposits are hazardous if they are large enough to provide zones of reduced gas velocity in their wake where crash-spilled fuel sucked into the engine may ignite readily. Large incandescent flakes of these deposits may be jarred loose in a crash. Upon discharge from the engine, they may ignite spilled combustibles. Further study of this type of engine-generated ignition source is needed. This problem may become important if slurry fuels are used for jet engines. These fuels, containing powdered metal, tend to leave larger deposits (metal oxide ash) than do the liquid fuels, which leave carbon deposits.

In the newer jet engines of higher pressure ratio and greater length, sufficient contact time may exist for ignition to occur on the hot metal in contact with the main gas stream. This point is the subject of further work in this field.

References

[1] Pinkel, I. Irving, Preston, G. Merritt, and Pesman, Gerard J., *Mechanism of Start and Development of Aircraft Crash Fires*, NACA Rep. 1133, 1954 (supersedes NACA RM E52FO6).

[2] Pinkel, I. Irving, and Preston, G. Merritt, *NACA Crash-Fire Research*, NACA Tech. Film 26, May, 1953.

Aluminum Alloys for Elevated Temperature Service

(*Continued from page 48*)

Acknowledgment

The Cleveland Research Division of the Aluminum Research Laboratories was responsible for the development of the new alloy composition XA140, and Charles B. Criner and J. Paul Lyle of the Aluminum Research Laboratories, New Kensington, Pa., for the development of alloys X2219 and M237, and the aluminum powder metallurgy products, respectively. The data on mechanical properties were obtained and organized by the Mechanical Testing Division, Aluminum Research Laboratories, New Kensington, under the supervision of F. M. Howell, Chief of the Division. The author expresses his sincere appreciation for the very active help of F. M. Howell and K. O. Bogardus in the preparation of this paper and of Robert Malcolm for the preparation of the figures and tables.

Inertial Navigation

(*Continued from page 52*)

to perform the operations in a high-performance aircraft, which is an extremely unfavorable environment.

That inertial systems have been brought to their present stage is a tribute both to the imagination of those in positions of responsibility in industry and in the Defense Department who dared to start the work years ago and to the scientific, engineering, and manual skill of those who have made it possible.

IAS News

(*Continued from page 23*)

Alcoa's Sales Development Division at New Kensington, Pa.

John F. Floberg (AM), former Assistant Secretary of the Navy for Air, has been elected to the Board of Directors of Piasecki Helicopter Corporation.

Kenneth M. Foreman (TM) has been promoted to Project Engineer and Section Head in charge of Ram-Jet Development Engineering, Wright Aeronautical Division, Curtiss-Wright Corporation.

Lawrence G. Fritz (M), one of the first air-line pilots, has retired as Vice-President—Flight of American Airlines, Inc. He joined American as Vice-President 10 years ago, following World War II service as a Brigadier General in command of the North Atlantic Division of the Air Transport Command.

George F. Hagger (AF) has joined Snap-Tite, Inc., Union City, Pa., as Director of Engineering. He was previously Director of Engineering of Aero Supply Manufacturing Company, Inc.

Lt. Col. Raymond R. Hajek, USAF (AF), has been appointed Chief of the Materials and Engineering Branch, Standardization Division, Directorate of Engineering, Air Research and Development Command. He also is a United States member of the NATO Working Group on Conversion of Specifications and Dimensions of Drawings for U.S. aircraft. Colonel Hajek was formerly stationed at Norton AFB, Calif.

Harvey T. Harrod (M) has been appointed Manager of Government Contract Administration for the Electronic Tube Division of Westinghouse Electric Corporation, Elmira, N.Y. He was formerly Aviation Manager of the Westinghouse office in Washington, D.C.

Roger Lewis (AM), former Assistant Secretary of the Air Force, has been elected an Executive Vice-President of Pan American World Airways, Inc., in charge of development and defense projects. Before entering Government service in 1953, he had been Vice-President of Curtiss-Wright Corporation.

John O. Montanaro (M) has joined the National Research Council of Canada in the Division of Mechanical Engineering and is living in Ottawa. He was previously with the British Ministry of Supply in London.

Peter Ovadias (M) has joined Linea Aeropostal Venezolana (LAV Air Line), Caracas, Venezuela, as Chief of the Engineering Department. He was formerly Professor on Aircraft Power Plants at the Academy for Air, Athens, Greece, and consulting engineer to two American construction companies building an air base in Creta, Greece.

Comdr. Louis G. Pooler, USN (M), has left the U.S. Naval Ordnance Test Station, China Lake, Calif., where he was Assistant Experimental Officer attached to the Research Department, to join the staff of the Aeroballistic Research Department of the Naval Ordnance Laboratory at White Oak, Silver Spring, Md., as Ordnance Applications Officer.

Ernest G. Stout

George E. Tubb, AMIAS, has been appointed Manager—Marketing of the Small Aircraft Engine Dept., General Electric Co., Lynn, Mass. He was formerly Vice-President of Lord Manufacturing Co.

Orville L. Richardson (M) is now a Test Engineer with Allison Division of General Motors Corporation, Plant 10, Weir Cook Municipal Airport, Indianapolis.

Robert E. Ricles (M) has joined Avco Manufacturing Corporation, Stratford, Conn., as an Aerodynamicist in the Advanced Development Division. He was formerly an Aerodynamicist with Douglas Aircraft Company, Inc., Santa Monica, Calif.

Joseph Shapiro (M), formerly with Convair, has joined Aerojet-General Corporation, Azusa, Calif., as a Senior Design Engineer in the Controls Department, Liquid Engine Division.

Ernest G. Stout (F) has resigned from Convair, San Diego, A Division of General Dynamics Corporation, where he has served in various technical, administrative, and executive positions. During the past 19 years with Convair he directed the hydrodynamic research and development that led to the world's first supersonic seaplane, the XF2Y Sea Dart, and the Navy's "flying LST," the bow-loading R3Y turboprop seaplane. For these developments he received the Lawrence Sperry Award in 1941 and the Sylvanus Albert Reed Award in 1953 from the IAS. Mr. Stout has joined The Ralph M. Parsons Company, of Los Angeles, as Assistant Manager of Business Development.

Henry C. Trich (M) has resigned as Sales Manager of the Hydraulic Division of Parker Aircraft Company to devote full time to his own business, Western Gravity Casting Company, located at 10,000 Exposition Boulevard, Los Angeles.

Jack Unger (AM), one of Canada's most experienced Arctic fliers, has been promoted to Check Pilot by Kenting Aviation, Ltd., of Toronto.

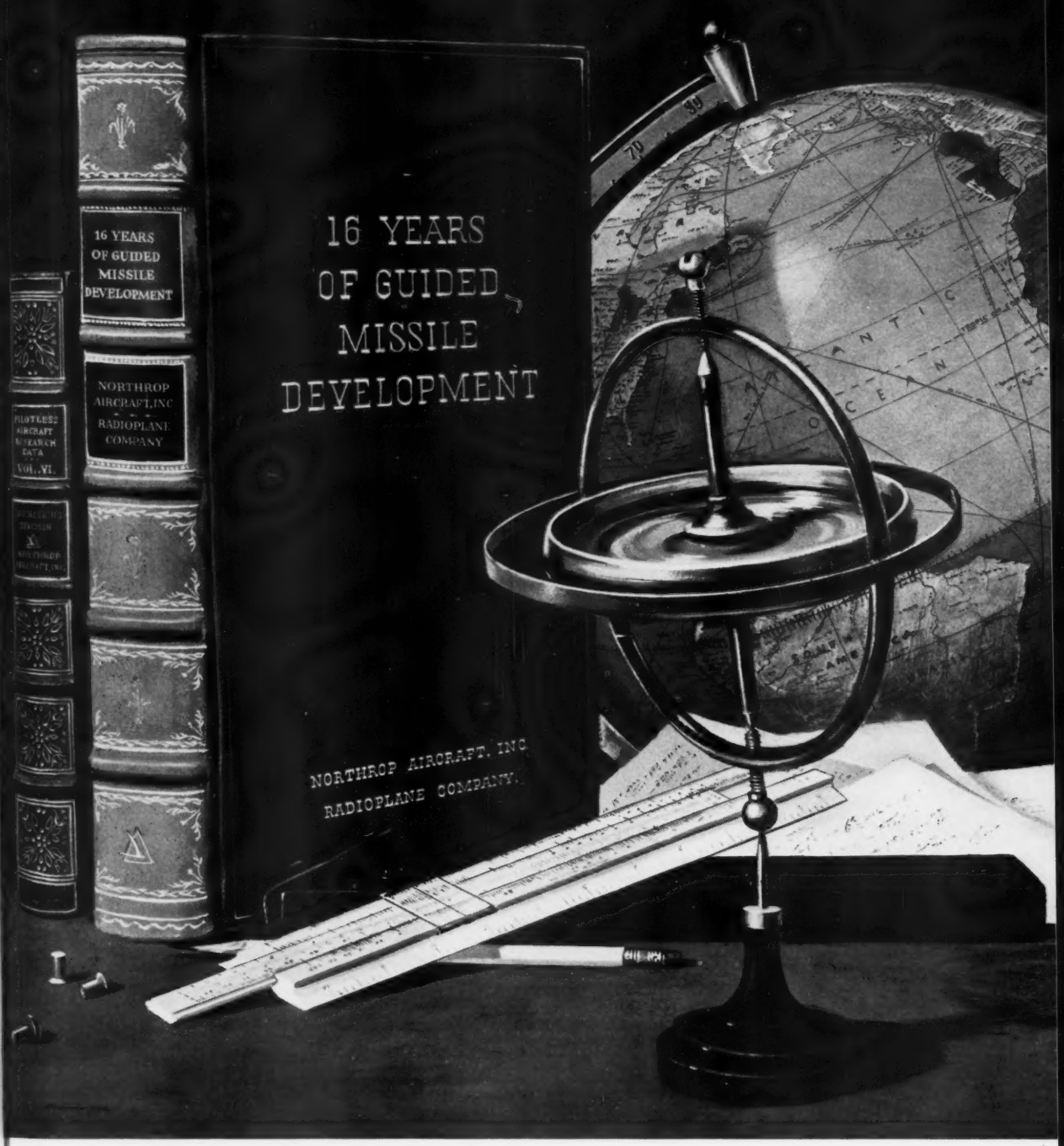
Theodore von Kármán (HF) has been named a Director and Chief of the Planning Board of Gruen Precision Laboratories, Inc., newly formed subsidiary of the Gruen Watch Company, of Cincinnati.

CORPORATE MEMBER NEWS

• **Aerojet-General Corporation** . . . As a result of recent demonstrations, rocket engine installations for emergency standby power are planned on some 25 business aircraft. The types include the Twin Beech, Lodestar, PV-1, DC-3, B-25, and B-26. The smokeless 15KS rocket engine, developed by Aerojet for the Navy Bureau of Aeronautics, delivers 1,000 lbs. thrust for 15 sec. Certain commercial air liners operating out of high-altitude airports in South America have been able to handle much larger pay loads by installing rocket engines for stand-by power.

• **Aeroquip Corporation** . . . Wayne G. English, formerly of the Ford Motor Company, has been named Treasurer of Aeroquip.

• **Air Associates, Inc.,** has developed a VHF radio navigation aid for pilots which broadcasts a voice bearing audible up to 50 miles. The "talking beacon" keeps aircraft on course by broadcasting bearing intelligence in a recorded female voice every 20° at intervals of 15 sec.; the pilot merely tunes in the desired or specified beacon station on his VHF receiver. The beacon, which includes three transmitters and three rotating antennas, can be transported by truck or helicopter and assembled in an hour.



BALANCE—Foremost of Northrop achievements is an efficient organization well balanced between the poles of advanced research and economical production. Northrop scientists in physics, astronomy, metallurgy, electronics, aerodynamics, optics and many other fields are doing their work *years* in advance of the need. From such long-range thinking and planning within the Northrop complex have come the Radioplanes, first and foremost pilotless drones and missiles; Scorpion F-89 interceptors, present defenders of our heartland approaches; and Snark SM-62s, deadly intercontinental A-bomb carriers. As streamlined as its products, the well-balanced Northrop organization is at work on even greater weapons to strengthen this nation's defense... and is more ready than ever to develop and produce them efficiently and on schedule.

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ANNOUNCING

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• **Airborne Accessories Corporation** announces Model R-580, a new a.c. or d.c. linear actuator rated at 650 lbs. maximum operating load and 2,000 lbs. ultimate static load. It weighs only 2 lbs.

• **Allison Division, General Motors Corporation . . .** Aeroproducts Operations, of Dayton, Ohio, is supplying emergency ram-air-driven hydraulic pumps for the North American F-100 and ram-air-driven generators for the Douglas A4D. In an emergency, the air stream is diverted over double-bladed variable-pitch propellers geared to the pump or generator which then produce enough power to operate the flight control surfaces. Another ram-air-driven emergency power unit developed by Aeroproducts has four automatically controlled variable-pitch propeller blades and develops 44 hp.

• **American Airlines, Inc.,** plans to operate the first transcontinental service of turbojet air liners, with daily flights beginning June 15, 1959. The tentative timetable lists 4 hours, 15 min. for the Los Angeles-to-New York flight and 1 hour longer for the westbound trip. American's 30 Boeing 707's, with Pratt & Whitney J57 engines, will cost about $4,500,000 each. The engines will be equipped with silencers and with "air brakes" to provide reverse thrust during the landing roll.

• **Avien, Inc.,** announces a new high-stability voltage source that provides constant d.c. output for measurement and control circuits through ambient temperatures as low as −55°C. and up to 100°C. Known as the *k*-Volt Standard, the unit is intended to replace the chemical cell and VR tube. It has no tubes nor moving parts and weighs less than 3 oz.

• **Boeing Airplane Company . . .** The 707 jet transport prototype has accumulated more than 319 hours of flight-test time, the company announced—the equivalent of more than five trips around the world. On two transcontinental flights the same day it averaged 592 m.p.h. eastbound and 567 m.p.h. westbound. . . . In letting subcontracts, Boeing has initiated a symposium system and has found it a timesaver. Instead of sending plans and specifications to interested firms, Boeing invited prospective subcontractors on the KC-135 program to send representatives to several different 2-day meetings. Boeing engineers made talks and answered questions. The same method has been used in awarding subcontracts for the B-52.

• **The Cleveland Pneumatic Tool Company . . .** William A. Roth, Vice-President and former Assistant General Manager, has been named General Manager.

• **Convair, A Division of General Dynamics Corporation . . .** Construction has begun on a $10,000,000 test and acceptance facility for F-102A's at the Palmdale, Calif. Airport. The new plant, to be operated by Convair-San Diego, will consist of nine major buildings with 500,000 sq.ft. of floor space. It will be on a 218-acre tract. Convair also operates engineering flight-test programs for the supersonic F-102A's at Edwards AFB and Holloman AFB. The planes are built in San Diego and flown to Palmdale Air Force Plant 42 for production flight testing and

Here is one of a series of advertisements we are running in FORTUNE and BUSINESS WEEK to acquaint company managements with our interest and our experience in the field of automation and data-processing.

We believe we are making good progress in developing activities that should ultimately give us a strong position in the tremendously important and rapidly growing field of automation.

Positions are available for scientists and engineers in these fields of current activity:

Business Data Systems Development

Digital Computer Research and Development

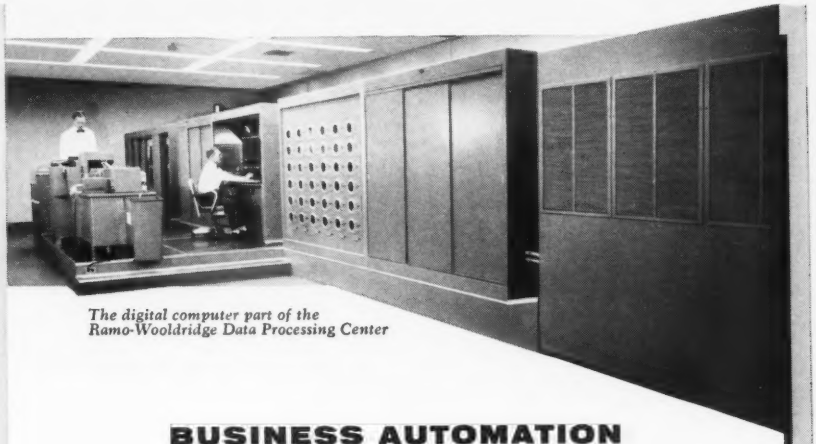
Radar and Control System Development

Communication Systems Development

Guided Missile Research and Development

The Ramo-Wooldridge Corporation

8820 BELLANCA AVENUE
LOS ANGELES 45, CALIF.



The digital computer part of the Ramo-Wooldridge Data Processing Center

BUSINESS AUTOMATION and MILITARY ELECTRONICS

The problem confronting many company managements today in deciding what course to follow in applying the new techniques of automation and data processing is similar to the problem faced in recent years by the leaders of our military organizations in arranging for efficient application of the same powerful tools of electronics to the art of war.

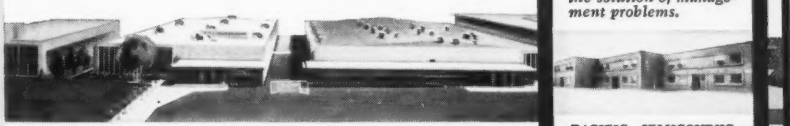
At Ramo-Wooldridge the difficult demands of major military systems responsibility have been met successfully by the placing of heavy dependence upon teams of unusually well-qualified, mature and experienced scientists, operational procedures experts, and engineers. These teams deal with the technical and non-technical portions of a project as inseparable and interrelated aspects of a single problem.

Similarly, work has been done in the last two years by this company on systems problems of non-military clients from such diverse fields as manufacturing, banking, transportation and public utility. The results strongly support the conclusion that many of the difficult problems in automation that face business and industry today can be economically solved by teams that include a breadth of technical and non-technical competence which permits them to conduct a highly objective, scientific analysis of a client's operations and requirements:

One important advantage to the client of such a broad and objective approach to his problems is the possibility of recommendations that realistic operational needs can be met without the necessity for investment in any additional machines or equipment. Nevertheless, the technical strength of The Ramo-Wooldridge Corporation, provided by its hundreds of scientists and engineers, is such that it can also undertake successfully the development of entirely new equipment and techniques, if required. As an example, major programs are currently under way on the development of an advanced type of digital computer and control system, and on the automation of large-scale data processing activities.

To a surprisingly great extent, military electronics experience has charted the course for non-military automation. A major objective of The Ramo-Wooldridge Corporation is to assist business and industry in moving rapidly, yet realistically and economically, to take advantage of the great benefits of the new techniques.

The Ramo-Wooldridge lecture hall during a lecture on Operations Research, as applied to the solution of management problems.



The Ramo-Wooldridge Corporation

8820 BELLANCA AVENUE • LOS ANGELES 45 • CALIF.

PACIFIC SEMICONDUCTORS, INC., *a subsidiary devoted to the development and manufacture of advanced types of semiconductor devices such as diodes and transistors...of great importance in the future apparatus of automation.*

The Convair TF-102A delta-wing trainer leaves the desert runway at Edwards AFB for its first test flight. Designed to carry two pilots side by side in the dual-control cockpit, the jet trainer has a wider nose section and canopy than the supersonic F-102A interceptor, and the air ducts for its J57 engine have been redesigned. A drag parachute is used in landing.

acceptance by the Air Force. . . . Convair is using chemically milled (etched) production parts on the delta-wing F-102A and has awarded its first subcontract for chemical milling. . . .The vacuum-cup principle is being employed at Convair's Fort Worth plant for moving aluminum sheet. Scratches and nicks must be prevented in the skin of supersonic aircraft. . . .A 60-in. solar furnace, made from the reflector of a surplus searchlight and capable of producing temperatures above 7,000°F., was exhibited by Convair at the World Symposium on Applied Solar Energy in Phoenix, Ariz.

• **Cornell Aeronautical Laboratory, Inc. . . .** Under a contract with U.S. Army Ordnance, the Laboratory will build an underground 1,000-in. firing range for research and development on aircraft small arms and ammunition. Costing about $31,000, the new facility will be used to study internal, external, and—to a limited degree—terminal ballistics of guns and small rockets. It may also be used to investigate the aerodynamic and stability characteristics of projectile bodies at supersonic speeds. In the past the Laboratory has done research on 20-mm. guns, with emphasis on obturation and heat transfer of the weapons and ammunition. It is now undertaking studies of 30-mm. weapons. The outdoor range previously used was considered unsatisfactory for safe, efficient, and well-instrumented experiments on large-size ammunition and higher-performing weapons.

• **Douglas Aircraft Company, Inc. . . .** Manufacture of the DC-8 jet air liner is under way at Santa Monica, where engineering, tooling, and production of parts are being handled. Final assembly of the DC-8 will be undertaken at another Southern California location, not yet announced. The company expects to have at least one DC-8 completed and ready for flight early in 1958. The first delivery to Pan American World Airways is scheduled for December, 1959. . . .Douglas is building a million-dollar altitude test chamber at its plant in Tulsa, Okla. The chamber will be 24 ft. in diameter and will provide automatic control for all variables involved in flight conditions at different altitudes. The variables to be measured and controlled include temperature (to −65°F.), pressure, air flow, and humidity. It will be possible to test portions of an aircraft fuselage or individual parts and assemblies under conditions existing up to 60,000 ft. On a more limited basis, flight conditions up to 120,000 ft. will be simulated. The test chamber will be controlled manually or programed in accordance with a preset time schedule. Sudden changes in temperature and pressure, including that of ram air and bleed air, will be simulated as encountered by jet aircraft and guided missiles.

• **Eaton Manufacturing Company . . .** The Aircraft Division in Battle Creek, Mich., has begun an $8,000,000 equipment and tooling program in preparation for the production of titanium compressor blading for jet engines. The titanium blades will be manufactured by the roll forging process that Eaton pioneered for steel blades. Titanium is superior to stainless steel in resisting corrosion and weighs only 60 per cent as much as steel, with comparable physical properties.

• **Elastic Stop Nut Corporation of America** has published a selection chart for its Agastat time-delay relay models. The correct model for a particular time delay or combination of time delays in an electrical circuit may be chosen by looking up specifications in the chart.

• **Fairchild Camera and Instrument Corporation** has established a Nuclear Instrumentation Department. Products under consideration for development and manufacture include radiation monitoring equipment, control rod drive mechanisms for atomic reactors, neutron detectors, and associated temperature, pressure, and flow controls. These controls and instrumentation systems will be designed mainly for commercial atomic power plants.

• **Fairchild Engine and Airplane Corporation . . .** Al-Fin Division has moved from Farmingdale to the new plant of the Fairchild Engine Division at nearby Deer Park, Long Island, N.Y.

• **Flight Refueling, Inc. . . .** A hose reel unit that permits in-flight refueling from remotely located wing-tip pods has passed WADC qualification tests and is going into production for use in the new tanker program of the USAF's Tactical Air Command, the company announced. The unit, similar to the A-12 hose reel built by Flight Refueling and standardized by the Navy for its refueling operations, has a capacity of several hundred gallons per minute. It has been flight-tested on a B-29 and is now installed in a prototype KB-50. With two wing-tip pods and a refueling unit trailing from the tail, this aerial tanker can refuel three fighters simultaneously.

• **The Garrett Corporation** has established the Rex Division to conduct a long-range research and development program in the field of aeronautics. . . . A new auxiliary power unit developed by the AiResearch Manufacturing Division provides electrical and mechanical or hydraulic power to operate guidance and control systems in guided missiles. It delivers 650 watts and can be up-rated when necessary to 1,600 watts. Either a liquid or solid propellant can be burned to direct gas against a turbine wheel which is mounted on the same shaft as an induction generator rotating at about 24,000 r.p.m. Lighter and smaller than previous units, it weighs 29 lbs. . . .A motor-driven cooling fan of revolutionary design, capable of operating for long periods at temperatures up to 260°F., is being produced by the AiResearch Manufacturing Division for use in pressurized radar indicators aboard Air Force bombers. The tiny fan weighs one lb.

• **General Electric Company . . .** The Aircraft Products Department, which produces armament systems for the B-47 and B-66 bombers, has constructed a dynamic accuracy tester that eliminates most of the flight testing necessary to evaluate new radar-directed, remote-controlled armament systems. At G-E's indoor firing range in Johnson City, N.Y., the tester is used to set up combat firing problems which the armament system's radar and computer must solve. System error can be checked and pin-pointed easily. . . .A loudspeaker capable of resisting humidity has been developed by G-E for Eastern Air Lines, Inc. The public address speakers are installed in air-conditioning ducts in the Martin 4-0-4 and Douglas DC-7B. . . .G-E has published a 24-page illustrated booklet describing its facilities for designing and producing complete aircraft electric systems. . . . Four nuclear research reactors are described in a new bulletin issued by G-E's Atomic Power Equipment Department.

• **The B. F. Goodrich Company** announced it is manufacturing airplane tires that have been tested successfully in temperatures as high as 280°F., under peak loads of 19,000 lbs., at landing speeds up to 170 m.p.h. The tires were designed for supersonic Air Force planes of the future. Last year, Goodrich announced it had developed tubeless airplane tires capable of making landings and take-offs at 300 m.p.h. under loads of 5 tons per tire. . . .A spray header using 82 ft. of Koroseal high-impact rigid pipe has been constructed for

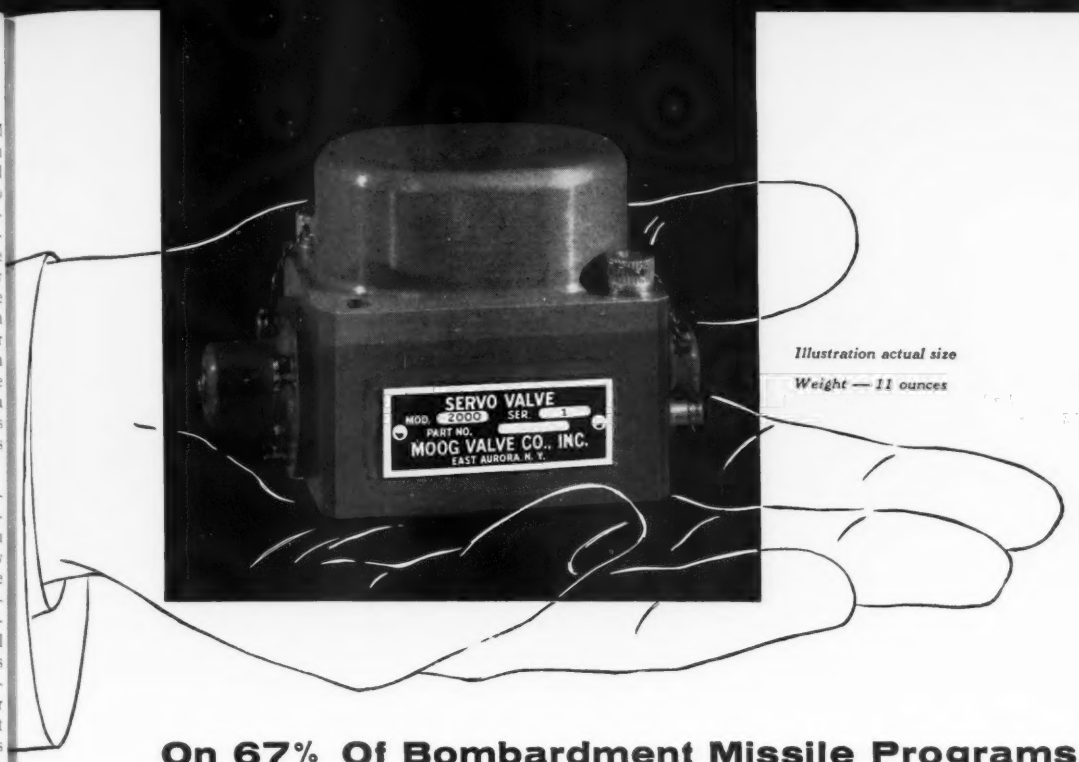


Illustration actual size

Weight — 11 ounces

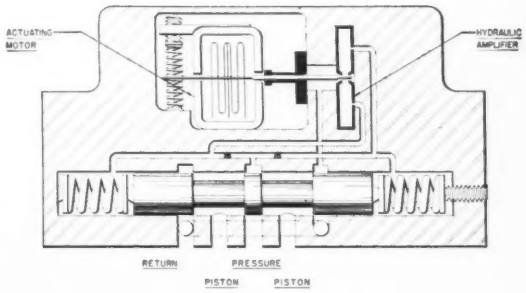
On 67% Of Bombardment Missile Programs
On 50% Of Fighter Aircraft Programs

Many thousands of Moog Servo Valves are now in use in exacting applications on advanced aircraft and guided missiles. This widespread usage attests to Moog features of reliability and high performance which have gained for these units recognition as the industry standard.

Now, these same features may be obtained in Moog's new Dry Solenoid Servo Valves. These units, illustrated above by Model 2000, feature a torque motor that is isolated from contact with the hydraulic fluid. The Dry Solenoids have been developed for those systems in which the fluid might otherwise contaminate the torque motor. They are even smaller and lighter than other Moog units of the same flow capacity and comply with requirements of MIL-H-5440A.

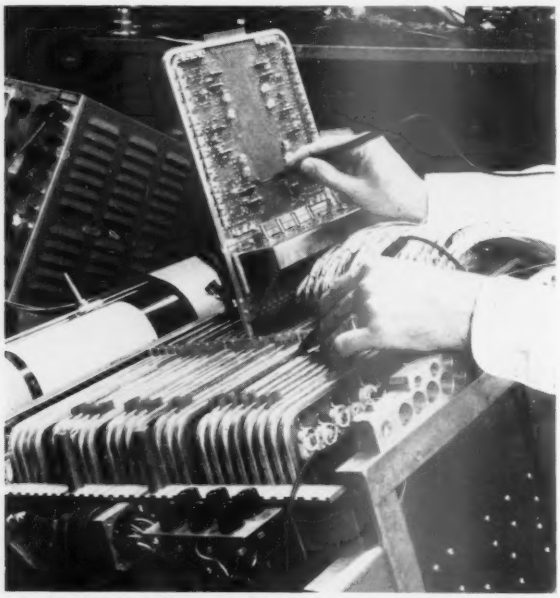
Moog Servo Valves are proportional type, electrically actuated, hydraulic, four-way valves featuring high dynamic response, sensitivity, linearity, small size and low weight. Production models are designed to operate in hydraulic systems of from 1000 to 3000 PSI pressure. Rated output flows from 0.1 to 50.0 GPM for control currents between 2.0 and 40.0 milliamperes as specified are available in production units.

Conventionally, valve input is from a balanced push-pull DC amplifier and valve flow output is applied to a piston or hydraulic motor. An electric signal proportional to piston position or motor angular rotation is fed back to the amplifier to give a closed servo loop.



For details write for Bulletin 2000-1

MOOG VALVE CO., INC. PRONER AIRPORT EAST AURORA, N. Y.



Circuits are checked in North American Aviation's new air-borne digital computer. Etched from sheets of copper-clad plastic and employing transistors instead of vacuum tubes, the electrical circuits are designed in the form of 51 standardized panels that can be pulled out like file cards for testing or replacement. The compact electronic brain automatically and continuously processes in-flight data.

use in a West Coast aircraft plant. It will spray parts following an acid pickle bath. Koroseal high-impact rigid pipe, the company says, is replacing carbon-steel, copper, cast-iron, and stainless-steel pipes in services where corrosion is a problem. In addition, it weighs only about one-fourth as much as metal pipe. This reduces handling time and shipping costs.

• **Harvey Aluminum Division of Harvey Machine Co., Inc.,** has published an eight-page illustrated bulletin describing its facilities for producing automatic screw machine products.

• **Industrial Sound Control, Inc.,** has designed silencers to quiet escaping gases and exhaust them vertically at the new ram-jet testing laboratory of Wright Aeronautical Division, Curtiss-Wright Corporation, Wood-Ridge, N.J. The silencers utilize the "soundstream" principle of sound elimination which channels the gases on an undulating course through a series of perforated metal silencers. The "free flow" design eliminates build-up of back pressure.

• **Jack & Heintz, Inc.** . . . The Dayton office has been moved to the Third National Building, 34 North Main Street.

• **Johns-Manville Sales Corporation** has issued a 12-page booklet, *Asbestos Safety Clothing*, describing the fireproof suits, helmets, mittens, aprons, overshoes, and other items made by J-M, including fireproof curtains for theaters and fire-smothering blankets used by firemen.

• **Kollsman Instrument Corporation** is constructing a new manufacturing plant on a 19-acre site in Syosset, Long Island, N.Y. The one-story building, to be completed next fall, will cover 157,000 sq.ft. and will contain assembly, machine shop, shipping, receiving, and other departments. Kollsman's main plant is located in Elmhurst, Queens, N.Y.

• **Lockheed Aircraft Corporation** has undertaken two major transport projects simultaneously—the long-range Super Constellation 1649A, to be ready in 1957, and the prop-jet Electra, due in 1958. The company announced recently it has redesigned the wing of the Electra to give it increased range and a shorter take-off run. With a practical range up to 3,000 miles, the 410-m.p.h. Electra will be able to cross the continent in about 6½ hours. . . .Lockheed's Georgia Division has contracted with the USAF to provide ground-school and flight-transition training for nearly 100 Air Force pilots and flight engineers who will fly the Hercules C-130 turboprop transport. . . .The Marietta, Ga., plant is using closed-circuit television, in combination with a surveyor's telescope, to speed the alignment of details in the large assembly jigs required for the C-130 Hercules.

• **North American Aviation, Inc.** . . . An air-borne digital computer in which transistors have replaced vacuum tubes has been developed for the Air Force and successfully flight tested by N.A.A.'s Missile and Control Equipment Operations. Installed in a high-speed plane, the computer will automatically and continuously process in-flight data. It has been miniaturized by using some 1,000 transistors, instead of vacuum tubes, and etched circuits, in place of conventional wiring. It occupies only 3 cu.ft. and weighs 125 lbs. Power required is less than 100 watts. A similar vacuum-tube computer with half the capacity would fill an average closet, weigh four times as much, and consume 3,000 watts. The capacity of North American's air-borne computer is indicated by the fact that it can continuously integrate 93 quantities simultaneously. It can generate continuous solutions of differential and trigonometric problems. . . . Looking toward the potential world market for commercial nuclear reactors, N.A.A. has established the Atomics International Division to handle the company's nuclear engineering and manufacturing operations. Atomics International employs 800 persons and has a new $1,500,000 building in the Canoga Park section of San Fernando Valley.

• **Northrop Aircraft, Inc.,** is constructing two new buildings and an addition to its plant at Palmdale, Calif., Airport, where final assembly and production flight testing of the Scorpion F-89 interceptor are conducted. The expanded facilities will be financed by and operated for the U.S. Air Force.

• **Pan American World Airways, Inc.** . . .A 15-unit electronic computer will be installed in the Long Island City, N.Y., office this spring to speed up accounting procedures. In addition to using the machine for billing and other routine purposes, the company plans to use it for crew scheduling and inventory control and possibly in connection with reservations control and payroll processing. Existing cargo and passenger records will be "mined" for statistics of value to the Sales Department. P.A.A. will rent the computer for $30,000 a month. It already uses more tabulating machines than any other air line, P.A.A. says. . . .A 40 per cent fare reduction has been placed in effect for military personnel coming home from Europe on furlough. . . . Pan American has inaugurated direct flights between New York, Haiti, and the Dominican Republic. There are three flights per week in each direction. . . . Free shuttle service to Idlewild Airport, via helicopter, is now provided to Pan American passengers who arrive at Newark or LaGuardia on domestic air lines. Reduced rates have been arranged with New York Airways for passengers who wish to begin or end their trips at Newark or LaGuardia.

• **The Parker Appliance Company** . . . Parker's new Exactol tube bender is a crank-operated, worm-gear device for easy manual bending to exact tolerances. It will readily handle annealed or ½H cold-drawn stainless-steel tubing. It produces accurate bends with no wrinkling, and any flattening will not exceed 5 per cent of the tube's outside diameter. The Exactol enables the operator to produce bends up to 180° in one continuous, smooth operation. . . .Milam Aircraft and Industrial Supply Company, of Dallas, Tex., has been appointed as a distributor of Parker synthetic rubber O-rings.

• **Piasecki Helicopter Corporation** has formed an Engineering Advisory Board to assist in formulating research and development programs in the field of vertical flight and in the solution of engineering problems. The three board members are Lee Arnold, AFIAS, of the Institute of Air Flight Structures, Columbia University; Courtland D. Perkins, AFIAS, Chairman of the Aeronautical Engineering Department, Princeton University; and Rene H. Miller, MIAS, of the Massachusetts Institute of Technology.

• **Republic Aviation Corporation** is in the midst of a $12,000,000 program to expand its research and development facilities. A supersonic wind tunnel capable of testing models up to Mach 4 will be built in

HOW A NATIONAL-STANDARD WIRE DEVELOPMENT *keeps her hair prettier all day long*

Millions of pounds of steel are used each year to make bobby pins.

And it's a tricky steel to make, as we learned while developing it . . . tricky, that is, if our customers were to avoid fabricating troubles and hold manufacturing costs to a minimum.

We had to produce a special kind of round wire that could be flattened without cracking. It had to have an extremely uniform finish to facilitate coloring and to permit high speed processing without frequent costly adjustments of machinery. It had to be suitable for tempering to give the right springiness and tension.

Not only did our engineers succeed in meeting all of these challenges, but they also were able to save our customers money on manufacturing, packaging and handling.

We solve problems like these every day for our customers and give them better, more complete service than they get elsewhere. That's why National-Standard is industry's foremost supplier of special wire, wire cloth and strip steel. May we serve *you*, too?

NS NATIONAL-STANDARD Company NILES, MICHIGAN

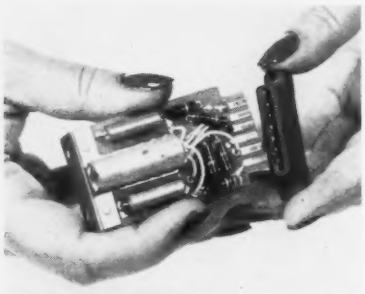
NATIONAL-STANDARD COMPANY • NILES, MICHIGAN
Tire Wire, Stainless, Fabricated Braids and Tape

ATHENIA STEEL DIVISION • CLIFTON, N. J.
Flat, High Carbon, Cold Rolled Spring Steel

REYNOLDS WIRE DIVISION • DIXON, ILLINOIS
Industrial Wire Cloth

WAGNER LITHO MACHINERY DIVISION • JERSEY CITY, N. J.
Special Machinery for Metal Decorating

WORCESTER WIRE WORKS DIVISION • WORCESTER, MASS.
Round and Shaped Steel Wire, Small Sizes



This small electronic "brain cell" is the basic building block unit for the master amplifier of Sperry's new helicopter control system. Interchangeable transistorized units plug into a block of sockets to form the complete amplifier.

the former plant of Fairchild Engine Division, which has been purchased from Fairchild Engine and Airplane Corporation and is adjacent to the Republic property in Farmingdale, N.Y. The Fairchild property will be used to expand engineering and experimental work on very advanced aircraft and guided missiles. The company announced it will make a concentrated research assault on problems arising from the thermal barrier. High-temperature structural and functional apparatus which can duplicate flight conditions above 50,000 ft., as well as test air frames to the breaking point, is being installed. Other new equipment will probe into aircraft performance at the −67° temperatures prevailing above 32,000 ft. New analog and digital computers that provide punched and magnetic-tape drives and automatic plotting are being installed, along with multichannel oscillographs, pickups, transducers, and telemetering and automatic data-recording equipment. Facilities will be constructed for testing engines developing up to 25,000 lbs. thrust, and a parallel noise-reduction program will be carried out, the company said. . . . The new Republic F-105 fighter-bomber is at Edwards AFB for flight tests.

• **R. Dixon Speas,** aviation consultant, and the New York engineering firm of Parsons, Brinckerhoff, Hall & Macdonald announce a joint engineering-consulting service available to municipalities, states, and other agencies responsible for planning and constructing airports to accommodate jet aircraft.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation . . .** After 4 years of development and flight testing, the Aeronautical Equipment Division has announced that a miniature, fail-safe flight-control system for helicopters is ready for production. The new electronic aid greatly simplifies manual control and provides automatic operation for hovering. The basic units weigh 60 lbs., including automatic trim devices and altitude and speed controls. In manual-automatic operation, gyros stabilize the ship on its existing flight path. The pilot can relax "hands off." All maneuvers can be executed many times more accurately than usual in adverse wind and weather situations. For automatic hovering, signals could be accepted from inertial devices in the helicopter or from submerged sonar units, ropes, cables, or ground command signals via radio or wire. The system automatically maintains altitude and heading. It also permits pilotless operation, such as might be required for an unmanned helicopter to lift special devices over a tactical position. A compact engine control developed jointly with the Wright Air Development Command automatically maintains constant rotor speed, relieving the pilot of the need to adjust throttles for every small change in rotor lift or loading. The ship's altitude is controlled according to barometric pressure, hydrostatic pressure, or other signals.

• **The Steel Products Engineering Company,** of Springfield, Ohio, has merged with the Kelsey-Hayes Wheel Company, of Detroit.

• **Union Carbide and Carbon Corporation . . .** Six new organo-silicone compounds with unusual lubricating and solubility properties have been developed by Linde Air Products Company. It is expected that they will find broad industrial uses as special lubricants, as release agents for rubber and plastics, in cosmetics, and as emulsifying agents or emulsion breakers. An eight-page data sheet is available.

• **United Air Lines, Inc.,** has announced plans to inaugurate service with jet air liners by November, 1959. The company will spend approximately $175,000,000 for 30 Douglas DC-8's equipped with Pratt & Whitney J57 engines.

• **Vickers, Incorporated . . .** Fourteen air lines and ten air-frame manufacturers were represented among the 96 engineers and maintenance supervisors who attended Vickers' Fifth Transport Aircraft Hydraulic Conference in Detroit.

IAS SECTIONS

Meet Your Section Chairman

George William Taylor

Seattle Section

A boyhood admiration for Charles A. Lindbergh led G. W. "Bill" Taylor to a career which for close to 20 years has kept him busy in air-line, Air Force, and aircraft work.

Now Manager of Domestic Sales for Boeing Airplane Company, Seattle, Bill was graduated an aeronautical engineer from the University of Alabama in 1932. In 1935 he joined the Pacific Division of Pan American World Airways, Inc., where he was assigned to the survey team that set up facilities at Midway, Wake, and Guam preparatory to inauguration of the air line's flying boat service to Manila later that year. He was in charge of the work at Guam.

Returning to San Francisco, he served successively as a maintenance engineer, project engineer for putting the Boeing Model 314 flying boat into service, and operations engineer for the air line. At the outbreak of World War II, he went to New York to serve as Administrative Assistant to the General Manager of Pan American Airways-Africa, returning to the Pacific Division in the fall of 1942 to serve successively as Assistant Division Engineer and Division Engineer.

A reserve first lieutenant in the Air Force, Bill went on active duty in January, 1944, as a technical inspector assigned to headquarters of the Seventh Bomber Command. After duty on several South Pacific islands and promotion to captain, he returned to Pan American in January, 1946, as Assistant Maintenance Manager of the Atlantic Division at LaGuardia Field, New York. In 1949 he was named Division Maintenance Engineer.

Bill joined Boeing in the summer of 1952 as a group engineer in Preliminary Design where he studied tanker requirements and aided in early documentation of the Model 707 jet tanker-transport prototype. He has held his present position since August, 1953.

No stranger to Boeing airplanes, Bill was assigned to the Seattle plant during construction of the Model 314 flying boats as assistant to Pan American's resident engineer and had charge of maintenance on the Stratocruisers as part of his Atlantic Division responsibilities for the air line.

Bill was program chairman of the IAS's National Turbine-Powered Air Transportation Meeting in Seattle in 1954 and in 1955. This year he is Chairman of the Seattle Section. He is a member of Tau Beta Pi and Delta Kappa Epsilon. His hobby is skiing.

He was born in Birmingham, Ala., in 1910 and in 1938 married Patricia Weisel, whom he met while assigned to

AN INSPIRING

ADVANCE

IN MINIATURE

RATE GYRO DESIGN

Peak Accuracy in a Capsule—Weighs only .7 pound, measures only 1½" by 3", yet resolution and threshold levels of new 2157-F gyro approach zero.

"Stiff-Cross-Axis" Torsion Bar—Radically improved torsion bar provides frictionless suspension, adds new stiffness to eliminate cross-axis flexure inaccuracies.

No Thermal Null Wander—Use of thermally compatible materials for all associated parts eliminates inaccuracies due to differing expansion qualities. Null doesn't vary with temperature.

Uniform Damping—Same temperature-conscious approach includes a greatly superior new method of damping the output axis to assure uniform dynamic performance from −65°F through +165°F. Twin compensating plungers operate in a special fluid within tiny steel cylinders in such a way that the relative thermal expansion of the parts compensates the thermal characteristic of the viscous fluid to provide uniform, frictionless damping throughout the temperature range. No heating of any kind is required.

Immeasurably Sensitive—With no frictional restraints of any kind on the output axis sensitivity is maximized.

No Wiping Contact—Electro-magnetic pick-off of output axis motion eliminates friction of conventional wiper-contact potentiometer for better resolution.

Rugged and Durable—Designed with partially floated gimbal for a guaranteed life of 1000 hours minimum, meets all applicable military specifications.

For complete engineering data write Lear, Inc., Grand Rapids Division, Grand Rapids, Michigan.

LEAR

IP-7

the Boeing plant. They have two children, William, 15, and Margie, 13.

Early professional work before joining Pan American consisted of 2 years with the Alabama Highway Department and a year in charge of a survey party for the Tela Railroad Company in Honduras.

Flight Control

Boston Section

The first fall meeting of the Boston Section was held November 2 in Cambridge at the M.I.T. Faculty Club. There were 130 members and guests present. Program plans for 1955–1956 were announced. Then Chairman Robert L. Halfman introduced the speaker, C. Stark Draper, Head of the Aeronautical Engineering Department and Director of the Instrumentation Laboratory at Massachusetts Institute of Technology.

Dr. Draper's subject was "Flight Control," and his material was drawn from his Wilbur Wright Memorial Lecture of last May before the Royal Aeronautical Society. He traced the development of the concepts of flight control from before the Wright brothers to the present time. He distinguished between inherent stability, which enables the airplane to fly straight without effort on the part of the pilot, and controllability, which permits the pilot to direct the flight path of the aircraft as desired. In the design of flying machines, these are opposing influences, since a craft having great inherent stability is steered with difficulty, whereas an easily steerable craft will require more effort in maintaining straight flight.

Early pioneers in aeronautics concentrated on achieving a high degree of inherent stability and were unable to achieve control of flight path. The Wright brothers designed their machine with low inherent stability and provided aerodynamic controls which were responsive enough to permit the pilot to restore the needed stability by use of these controls. This arrangement also made possible control of flight path. Dr. Draper pointed to the Wright brothers' background with bicycles as being of importance in this connection.

The next significant step was the automatically controlled flight made by Lawrence Sperry in 1914. Here the detection of departure from straight flight and the consequently needed corrective action was accomplished by an automatic pilot. Operational use of this technique came much later, beginning with Wiley Post's 'round-the-world flight of 1932.

These autopilots made use of newly developed blind flying instruments as attitude references. In the past decade, with the advent of the higher speeds of jet aircraft, there has been a trend toward the use of automatic control equipment, the purpose of which is to augment the stability of the aircraft. This is occasioned by the poorer inherent stability accompanying higher speeds. Dr. Draper said that this approach to flight control still remains to be accepted by those who believe that the airplane configuration should and can have adequate aerodynamic stability.

Dr. Draper's talk was followed by a discussion which centered around the Wright brothers' attitude toward flying on windy days.

(T. J. Keating of WADC reviews a similar talk by Dr. Draper in the news report from the Dayton Section, p. 71.)

WALTER MCKAY, *Secretary*

It's Air-Borne

Colorado Section

Fifty-five men met at the Denver operating base of United Air Lines, Inc., on September 23 to form a new Section of the IAS—the twenty-sixth Section.

After a steak dinner, the meeting was called to order by Alison M. Arnold, of Stanley Aviation Corporation, who explained the purpose of the meeting and described the IAS. Major Vincent J. Bracha, USAF, of Air Defense Command Headquarters, Ent AFB, was elected Temporary Chairman.

Major Bracha took the chair and suggested a tentative program for the new Section which he had prepared previously in collaboration with Richard Frost, Vice-President of Stanley Aviation Corporation. Major Bracha proposed four dinner meetings per year, to be held in rotative fashion at Denver, Colorado Springs, and Boulder. These affairs, he said, might be sponsored by the larger aeronautical groups in these areas—namely, United Air Lines, Lowry AFB, the U.S. Air Force Academy, Stanley Aviation Corporation, the University of Colorado, and the Air Defense Command.

Mr. Frost was named Chairman of the Nominating Committee, assisted by K. D Wood, Major W. R. Fuchs, and W. Lawrence.

The Membership Committee was appointed, as follows: Herbert G. Hubbard, representing United Air Lines, Inc.; J. Connelly, Beech Aircraft Corporation; C. E. Wadell, University of Colorado; A. M. Arnold, Stanley Aviation Corporation; Lt. Col. G. L. Clementson, Air Force Academy; Lt. Col. W. A. Larsen, Air Defense Command; J. Greenbaum, Denver Soaring

RECORD SIX YEAR PRODUCTION PAVES WAY FOR NEW GIANTS

Largest airframe assembly subcontracted. Ryan is producing huge aft fuselage sections for the Boeing KC-135 jet tanker-transport. This new project follows six years of continuous on-time production of fuselage sections for Boeing's KC-97.

It's a tail of two cities. The huge structures built by Ryan in San Diego must mate perfectly with sections produced at Boeing's Seattle-Renton plants. This demands precision manufacturing, perfect planning and flawless coordination.

Techniques, planning and skill save money. Ryan reduced costs 40% during production of KC-97 assemblies. This saving was passed on to Boeing and the Air Force – to provide more aircraft per defense dollar. This is just one example of the outstanding cost-performance at Ryan. The same manufacturing efficiency and smooth integration is found in the production of fuselage sections for Sabre Jet fighters and other military and commercial airframe components such as fuel tanks, control surfaces, wing sections.

Established, financially stable. Ryan performs subcontracts without progress payments from customers. A veteran of 33 years exclusively in the aircraft business, Ryan understands the industry's problems as only an aircraft company can. It has the modern facilities, most advanced manufacturing techniques, and highly skilled engineering and technical personnel needed to produce the industry's most difficult production assignments.

For 33 years, Ryan has excelled in designing and producing high quality aircraft, power plants and avionics—built at low cost, delivered on time.

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Club; and Mr. Hauter, Continental Air Lines, Inc.

A formal petition to the IAS was drawn up. Since then, IAS Headquarters has approved the formation of the Colorado Section.

The second meeting was scheduled for December 2 at Colorado Springs. Professor Wood suggested that the spring meeting be held in Boulder, as the University of Colorado would have excellent program material at that time.

After the business meeting, a tour of the United Air Lines base was conducted by D. R. Petty, Vice-President—Flight Operations, and A. F. Bonnalie, Director of Training—Flight Operations.

The program consisted of observation of a management briefing session in which the air-line operations for the past 24 hours are summarized. Specialists in maintenance, customer service, and base operations conduct the briefing for the various vice-presidents and other management heads. After the briefing, executive action is taken to rectify operational problems.

Aircraft discrepancies and availability are shown, along with the distribution of the maintenance work load. at the various operating locations. Time delays caused by maintenance work and aircraft discrepancies are reported. Space usage and availability are reviewed. The passenger volume is about 17,000 per day. Special charter operations, with particular reference to flights for football and baseball teams, are reported. Base operations are reviewed, and all phases of performance are compared with the previous year's performance and with established acceptable limits. It was interesting to note that a complete profit and loss statement for the past 24 hours is made available to W. A. Patterson, President of U.A.L., by 9:00 a.m. of the following day.

The visitors were then shown the statistical performance records of the various specific aircraft types regarding engine changes, discrepancies, and base maintenance requirements—including man-hours required per routine check. Comparison of the current year's operation with last year's is made graphically, considering specifically each component and the maintenance requirements.

The central passenger reservation clearance room and a communications system capable of connection with any U.A.L. passenger reservation service were demonstrated. Operation of the system costs 52 cents per min. All reservations are taken by wire recordings, so that clerks can use them at a slower pace and then take the necessary action such as confirmation, holding, etc.

The tour ended with demonstration of a DC-6B Dehmel flight simulator. The apparatus was extremely realistic in its duplication of flight. Instrument performance, coupled with realistic sounds and deck vibration, made even an onlooker feel that he was becoming air-borne at take-off speed. Several of the visitors were permitted to fly the simulator. Naturally, one of them stalled the airplane and wound up in an impossible spin which was concluded with a crash—sound and all.

A. M. ARNOLD, *Acting Secretary*

Columbus Section

L. A. Duffey, Preliminary Design Weight Engineer of North American Aviation, Inc., Columbus, Ohio, discussed the general problems of preliminary design weight estimation at the October 18 meeting of the Columbus Section.

The general goal of the weight engineer is to promote the highest practical product. In preliminary design this starts by estimating a take-off gross weight based on useful load (crew, armament, and fuel for fighter airplanes) plus engine weight.

This estimated take-off gross weight then goes into the structural weight equations along with detail geometry and design items such as flaps, location and design; wing fold location; wing thickness, aspect ratio, taper and area; fuselage wetted area; design load factor; and detail equipment weights.

Many items of the design work at cross purposes in the final airplane weight. Some details of the geometry such as decrease in wing thickness and increase in sweep may decrease the drag but increase the weight. The final airplane must be a compromise which gives the desired mission performance with the minimum equipment in order to have the desired lightest practical gross weight.

JAMES T. OVERBEY, *Secretary*

Flight Control

Dayton Section

An after-dinner lecture on "Flight Control" was presented by Charles S. Draper, Head of the Aeronautical Engineering Department of Massachusetts Institute of Technology, at the October 13 meeting of the Dayton Section. About 250 members and guests heard the talk, which was based on the paper Dr. Draper delivered as the 43rd Wilbur Wright Memorial Lecture before the Royal Aeronautical Society in London, England, last May.

The early philosophy of aircraft control and stability was reviewed and evaluated. It was pointed out that the Wright brothers' predecessors provided a high inherent stability in their aircraft. As a result, earlier flying machines possessed low controllability and maneuverability and responded to gusts readily. The Wright brothers broke with the "inherent stability" concepts and deliberately made their airplane marginally stable. The pilot acted as the human servo which closed the control loop and provided the necessary feedback to achieve an overall stable system. This stabilization was provided with accompanying good controllability and maneuverability.

In addition, the contributions, both experimental and theoretical, to the art of airplane control were reviewed from a historical viewpoint. Included in the topics were flight control before the Wright brothers, early aeronautics, the Wright brothers' airplane, instrument flying, coordinated control systems, navigational autopilots, and all-maneuver flight-control systems. Comments were made by Dr. Draper on estimates of the interest and activity in areas associated with flight control versus time from 1900 to the present.

An interesting opinion uncovered during discussions following the lecture was that control systems with few electronic tubes are probably not too good. The more tubes the better.

(For Professor Walter McKay's summary of a similar talk by Dr. Draper, see the news report from the Boston Section, p. 69.)

T. J. KEATING, *Secretary*

The Viscount

Hagerstown Section

The first part of the October meeting was held on the 25th in the Museum of Fine Arts, Hagerstown. Chairman Allen Clopper appointed committee chairmen and discussed their responsibilities and aims for the coming year.

Program Chairman W. H. Arata, Jr., introduced the speaker, Hugh F. Jacox, Assistant Sales Promotion Manager of Capital Airlines. Mr. Jacox discussed the reasons (economy and maintenance) for introducing an English-manufactured commercial transport in this country and described the unusual features of the Vickers Viscount.

He showed a promotion film, *New Concept in Flight*, covering construction of the air frame and the Rolls-Royce Dart engine. Seventy-five members and guests were present.

The second part of this meeting consisted of a field trip to the Capital Airlines Maintenance Hangar at Washington National Airport, where 33 members and guests saw the Viscount undergoing its 50-hour inspection.

C. L. CHUMLEY, JR.
Secretary-Treasurer

Officers of the Hampton Roads Section welcome their former colleague Abe Silverstein on his visit to Langley Laboratory to speak at their October meeting. He is shown shaking hands with Chairman Albert L. Braslow. From *left to right* are: Thomas L. Fischetti, Charles H. Zimmerman, Braslow, Emanuel Boxer, Silverstein, Lewis R. Fisher, Franklin W. Diederich, and James P. Shivers.

Hampton Roads Section

The November 1 meeting at the NACA Langley Laboratory featured a discussion of "Some Considerations of Design and Applications of Jet VTO-Type Aircraft" by John M. Herald and Robert A. Fuhrman, both of the Ryan Aeronautical Company, San Diego. The meeting, which was classified, was attended by some 85 members and guests of the Section.

Mr. Herald, who is the Head of Development Planning—Military Relations, at Ryan, discussed the operational advantages of VTO aircraft over conventional aircraft with the aid of slides and movies. He described the early efforts of Ryan to gain VTO experience by means of test vehicles. This work was culminated by the design and construction of the X-13 jet VTO research airplane.

Mr. Fuhrman is the chief of the Technical Section of the Engineering Division and is in charge of all structures, aerodynamics, stability and control, dynamics, and systems analysis work at Ryan. He compared the technical considerations involved in the design of a VTO airplane with those for a typical fighter airplane, which might now be in the development stage, from a weight-wise standpoint and discussed some areas in which weight-saving might be accomplished. Mr. Fuhrman described some of the performance characteristics of a typical jet VTO fighter and discussed some of the stability and control problems that may be encountered.

▶ The first meeting of the Hampton Roads Section on October 18 was attended by 120 members and guests. Chairman Albert L. Braslow opened the meeting by introducing the other newly elected officers: Vice-Chairman Franklin W. Diederich, Corresponding Secretary James P. Shivers, Recording Secretary Lewis R. Fisher, and Treasurer Thomas L. Fischetti. The Advisory Board is composed of Henry J. E. Reid, Charles H. Zimmerman, Jean A. Roché, Melvin N. Gough, Emanuel Boxer, and H. Herbert Jackson.

Many friends and former associates were present to welcome the speaker, Abe Silverstein, who formerly headed the Full-Scale Tunnel at Langley Aeronautical Laboratory, NACA. Mr. Silverstein, a Fellow of the IAS, is now Associate Director of the NACA's Lewis Flight Propulsion Laboratory in Cleveland. Introduced by Samuel Katzoff, he made a confidential talk on "Implications of Current Propulsion Problems on Aircraft Design."

A dinner in Mr. Silverstein's honor, preceding the meeting, was attended by the Section officers, members of the Advisory Board, and other friends of the speaker.

LEWIS R. FISHER
Recording Secretary

Los Angeles Section

The first dinner meeting of the 1955–1956 season was held in the Institute building on September 15 and was called to order by the outgoing Chairman, Warren Dickinson. Mr. Dickinson summarized the activities of the Los Angeles Section for the preceding year, noting that a total attendance of 11,853 people had been served at the 54 meetings.

Mr. Dickinson noted two gifts to the IAS, both of which are on display in the building. An Early Bird mural painted by Justin Gruelle was donated by The Liquidometer Corporation through Clarence deGiers and is now hung on the inner wall of the lounge.

Dr. and Mrs. Gabriel Giannini donated a bust of Theodore von Kármán sculptured by Gualberto Rocchi of Italy.

The new officers of the Section were introduced by Mr. Dickinson. They are: George Mellinger, Chairman; Welko Gasich, Vice-Chairman; Joseph Wechsler, Treasurer; and Richard Fuller, Secretary. At this time Mr. Dickinson turned the meeting over to Mr. Mellinger.

Mr. Mellinger introduced the principal speaker of the evening, Willis M. Hawkins, Director of Engineering of the Missiles Systems Division of the Lockheed Aircraft Corporation.

In his talk, "New Responsibility of Science and Engineering in the Weapon Systems Development," Mr. Hawkins observed that the aircraft industry has in the past attempted to predict a product market from 5 to 10 years hence and then set out inventing the predicted product. Now, due to competition, invention will not suffice, and major scientific breakthroughs are required.

To meet this challenge, practical engineering must merge and work with pure science. It is the responsibility of the Weapon System Management to create and maintain a balance between the practical engineer and the pure scientist. The engineer and the scientist are responsible for creating new concepts and time schedules. Long lead times make failure of these responsibilities most uncompromising. Similarly, it is important that if the concepts or schedules created become impossible, management must be informed promptly. Seven dangers should be recognized:

(1) *The almighty formula.* We must develop maturity and substitute brains for equations.

(2) *The impossible concept* wherein the customer requests the impossible and the engineer promises to deliver.

(3) *The scientific monument* which typifies the solution of a problem the hard way, showing scientific ingenuity but not intelligence in developing the product.

(4) *The entrenched idea* or "NIH," which means that if it was "not invented here" it isn't any good.

(5) *Following the uncompromising specification* because it is written down, when development work shows the requirements to be erroneous.

(6) *The disregarded customer* whose ideas are ignored by the technician and replaced with complex concepts. This requires the customer to hire technicians to check the work of the manufacturer, and then two technicians are required to do the work of one.

(7) *The misuse of engineering talent* in which engineers and scientists are

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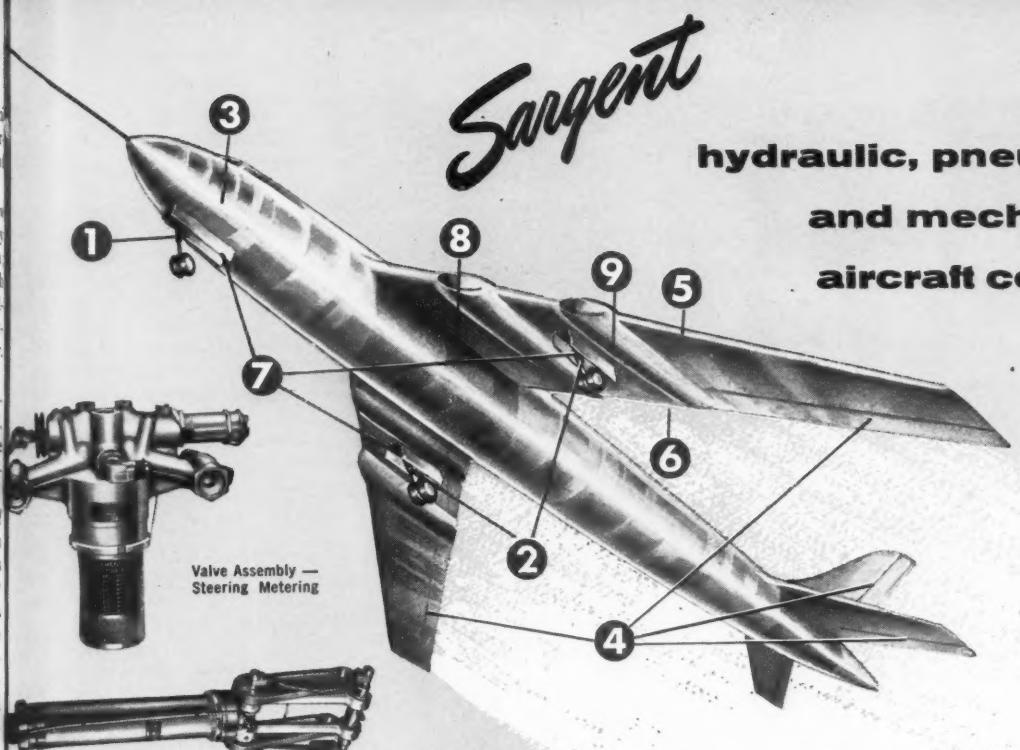
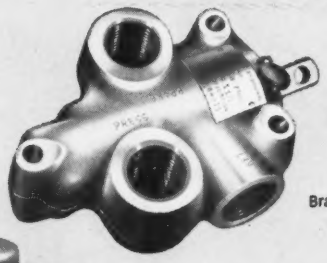
hydraulic, pneumatic and mechanical aircraft controls

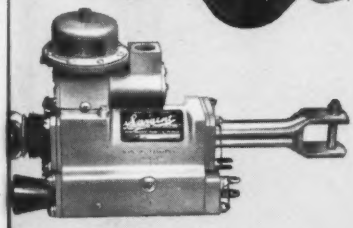


Valve Assembly — Steering Metering

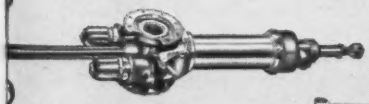
Main Landing Gear Retractor



Brake Valves

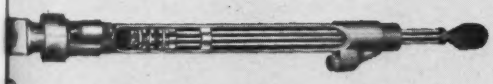


Power control units for rudder, elevators and flaperons



Slat Actuating Cylinder

Gear Box Assembly — Outer Wing Flap Drive



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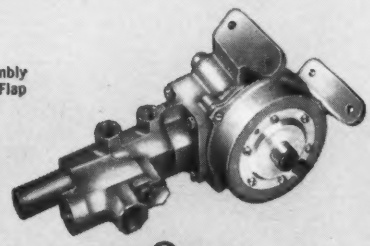
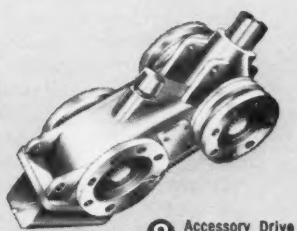
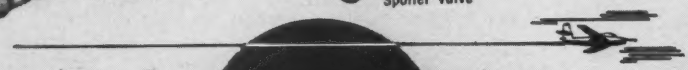


8 Spoiler Valve



9 Accessory Drive Power Take-off



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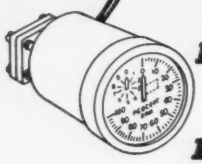

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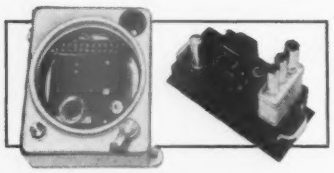
The TAKCAL operates accurately in all ambient temperatures from —40°F. to 140°F. Low in cost for an instrument of such extreme accuracy, it is adaptable to application in many other fields.



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switched from technical to managerial responsibilities or force their way into these assignments out of egotism when they have demonstrated little or no talent in management.

This last danger must be avoided by creating a pattern of rewarding the engineer and the scientist for technical work only. Mr. Hawkins concluded ithat the engineers and scientists must encourage industry and the military to nclude in their policies support of pure research within the industrial framework and that, in turn, the engineers and scientists must not force their way out of their chosen field unless they have a proved talent for managerial status.

R. G. FULLER, *Secretary*

▶ At a specialist meeting of the Los Angeles Section on October 25, Oscar Hoffman of the Cleveland Pneumatic Tool Company presented a paper on "Mechanical Factors Affecting the Strength of Aircraft Structural Alloys" to an audience of about 70 IAS members. He confined his talk to effects of stress concentrations on the strength of structural alloys. With the use of slides he showed failures that had occurred as a result of stress raisers and how the material in the vicinity of these stress raisers which induce biaxial and triaxial stress conditions affects the allowable loads. He emphasized the need for more realistic tests in further studies of the subject.

F. R. STEINBACHER
Specialist Meetings Committee

▶ At a specialist meeting on October 11, Lester Lees of the California Institute of Technology presented a discussion of "Recent Theoretical Work in Rarefied Gas Flows." He showed that for high-altitude flight, slip effects at solid boundaries will become important. Earlier treatments—e.g., those of Chapman and Jaffe—of flows which depart from that described by the Vanier Stakes equations were essentially expansions in the mean free path or its reciprocal and failed to converge over large regions of interest. The kinetic theory formulation of Grad, in which the velocity distribution function is expanded in a series of generalized moments, was shown to reduce to a tractable equation for the case of an infinite insulated plate suddenly set into motion. Approximate solutions were developed which agreed with the solutions of Chapman and Jaffe at the extreme and faired smoothly in between.

J. L. FOX
Specialist Meetings Committee

▶ At a specialist meeting held on September 29, Carl D. Vrooman of Lockheed Aircraft Corporation gave a discussion of "The Lockheed Icing Research Tunnel." He noted the many

MISSILE SYSTEMS

AERODYNAMICS

The rapid growth of missile systems technology has placed new demands on the ability of aerodynamics scientists. At Lockheed Missile Systems Division, new advances are required constantly in thermodynamic analysis, aerodynamic design analysis, flutter, aero-elastics and flight dynamics.

Continuing experimentation at Jet Propulsion Laboratory, Ames Aeronautical Laboratory, Gas Dynamics Facility at Princeton University, Naval Supersonic Research Laboratory at Massachusetts Institute of Technology, Langley Memorial Laboratory and other centers supports this program of expanding aerodynamic activities.

These advances have created new positions for aerodynamics scientists possessing advanced academic training in the following areas:

■ **Design Aerodynamics Engineer** to perform theoretical analyses and evaluate experimental data on high-speed flow phenomena as related to performance and stability characteristics of missiles or supersonic aircraft. The position requires at least five years' related experience.

■ **Experimental Aerodynamics Engineer** to plan, supervise, analyze and report on experimental programs. The position requires a sound background in supersonic aerodynamics and at least five years' experience, preferably in wind tunnel testing or full-scale and free flight model testing.

■ **Experimental Aerodynamicist** to assist in planning and reporting on experimental programs. The position requires one to two years' experience in wind tunnel testing or full-scale and free flight model testing.

Those who wish to advance their professional stature, while contributing to a group effort of utmost importance, are invited to write.

Lockheed **MISSILE SYSTEMS DIVISION**

research and engineering staff

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factors influencing the design and operation of an icing wind tunnel. He indicated that steady-state operation could not be maintained for indefinite periods because of the build-up of ice on protuberances in the tunnel such as turning vanes and prerotation vanes. His talk was illustrated by slides and a complete history of the tunnel construction in 16 mm. color film. An application of the tunnel was illustrated by movies showing a wing section being deiced by hot air under typical icing conditions.

EDWARD F. VERSAW
Specialist Meetings Committee

The Viscount

Niagara Frontier Section

Hugh F. Jacox, Assistant Sales Promotion Manager of Capital Airlines, discussed technical features of the Vickers Viscount airplanes at the October 12 meeting. Sixty of these 40–44 passenger turboprop air liners are now entering Capital's service. The Viscount was selected to provide new equipment best suited to Capital Airlines' route system, which features medium-range flights over highly competitive routes. The basic need was for essentially short-haul aircraft with performance comparable to the long-range aircraft used by competing air lines.

The Viscount cruises at between 325–335 m.p.h.; optimum cruising altitude is 21,000–23,000 ft. Operation from all airports now served by Capital with DC-3 and DC-4 aircraft will be possible. An automatic water-injection system is provided. The majority of flights will be 600 miles or less in length, although the airplane has a range of 1,500 miles. Fuel consumption is approximately 400 gal./hour; the four Rolls-Royce engines burn kerosene, which costs half as much as 100-octane gasoline. Reverse pitch for braking is not available, but the propellers automatically go into the low-pitch position when the engines are throttled back and provide considerable deceleration during the landing roll.

Approximately 70 of these million-dollar aircraft are already in service on air lines throughout the world, and orders now total over 200. Rolls-Royce and Vickers-Armstrongs have established facilities in the United States to service Capital's fleet of 60 airplanes.

The airplanes are equipped with Bendix autopilots and the Collins Radio "integrated flight system." Storm-warning radar will be featured on later aircraft.

A color motion picture described the aircraft and engine manufacturing processes and highlighted many of the passenger-comfort and convenience features, including pressure cabin, carry-on baggage rack, low noise level, absence of vibration, large windows, and built-in tables.

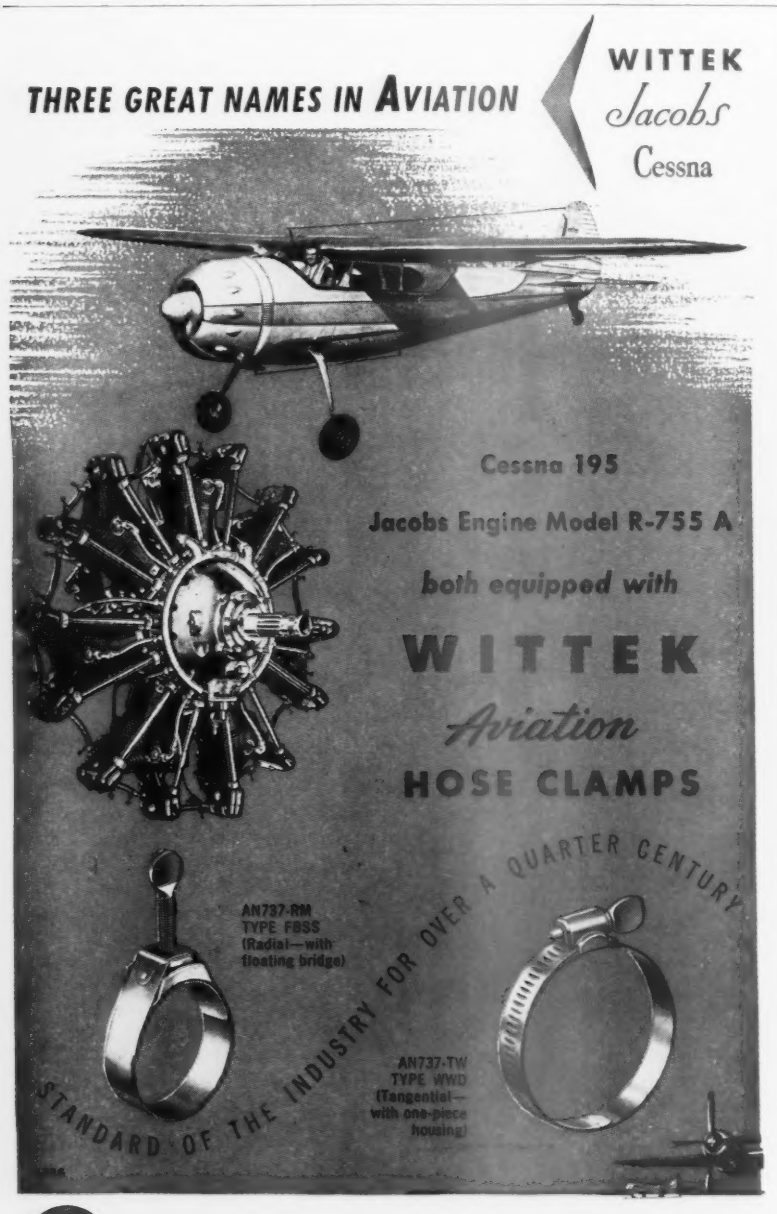
Mr. Jacox stated that three Viscounts were then in service and that more will be added at a rate of about five per month. Service to Buffalo is forecast for February–March, 1956. Experience to date has been excellent, and the aircraft have required little maintenance.

DAVID WHITCOMB, *Secretary*

St. Louis Section

Four experienced test pilots presented their views on the flying qualities of jet fighters at the meeting held at the Engineers Club on October 26. The group was composed of Major James J. Butler, Chief of Fighter Operations Section, Wright-Patterson AFB, Ohio; Commander Robert J. Selmer, Assistant Director of Test Pilot Training, NATC, Patuxent, Md.; Robert A. Champine, Experimental Test Pilot, NACA, Langley Field, Va.; and Major Stuart R. Childs, Chief of the Fighter Test Branch of the Directorate of Flight Test and Development, Edwards AFB, Calif.

Subsequent to his introduction by J. C. Kippenhan, 1955–1956 Vice-

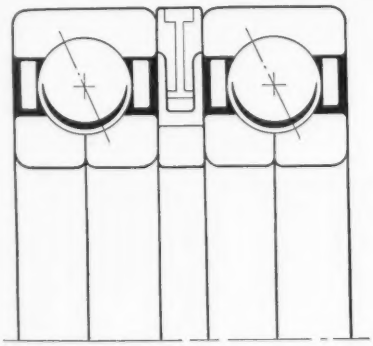


FACTS

about

NEW DEPARTURE

BALL BEARINGS FOR JET ENGINES



Matched sets of New Departure split inner ring bearings are made with great accuracy to assure equal distribution of the heavy thrust loads developed by modern aircraft engines.

New Departure is bringing to bear the most extensive facilities in the industry for the research, development, testing and production of ball bearings for jet and turboprop engines . . . bearings made of heat-stabilized ball bearing steel and special high-temperature alloys for maximum service at elevated temperatures and high speeds . . . ball bearings designed to operate under adverse conditions of lubrication . . . bearings fully capable of taking the heavy thrust loads existing in high-performance jet and turboprop engines.

Indication of New Departure's knowledge and experience in the production of the specialized bearings required for modern aircraft performance is the split inner ring types shown above, being made for all the major jet engine manufacturers in America.

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These four test pilots discussed the flying qualities of jet fighters at the October meeting of the St. Louis Section. From *left to right* are: Major James J. Butler, Wright-Patterson AFB, who also acted as moderator; Comdr. Robert J. Selmer, Naval Air Test Center, Patuxent, Md.; Major Stuart R. Childs, Edwards AFB; and Robert A. Champine, Langley Aeronautical Laboratory, NACA.

Chairman, Major Butler as panel moderator outlined the discussion plan and successively introduced Commander Selmer, Mr. Champine, and Major Childs.

Commander Selmer discussed carrier qualities and the carrier pass. He commented on stall speeds, rate of roll, elevator effectiveness, engine acceleration time, and structural requirements. He then explained that pilots at the NATC must have extensive operational background to enable them to temper all specification requirements with sound judgment, since they are required to certify that an airplane may or may not meet specification requirements but in turn may or may not be satisfactory from a pilot standpoint.

Mr. Champine discussed the landing of high-speed aircraft. He limited his discussion to daytime, good-weather operation only and then proceeded to comment on correct rates of descent, the necessity for forward speed to be on the high side, the turning approach, the power used to assist in obtaining the correct rate of descent, and the need for the correct attitude upon touchdown. He discussed the need for precise control at slow speeds and the necessity for coordination of power and bank angle in maintaining constant air speed.

Major Childs made a qualitative presentation of inertia coupling problems. He stated that a single flight in any particular airplane can reveal an inertia coupling problem if it is a limiting one. He discussed the restrictions of controls required and the need for cutting down rates and gave a presentation of current improvements in pitch damping.

Major Butler then resumed charge of the meeting. He and the other test pilots answered a number of prepared questions. More than 200, including 85 guests, attended this confidential meeting.

Allen H. Madrick has resigned as Chairman of the St. Louis Section, having left McDonnell Aircraft Corporation to accept a position in another city. Hermon H. Cole, Jr., succeeded him as Chairman.

FREDERICK H. ROEVER
Recording Secretary

Tullahoma Section

At the invitation of the Alabama Chapter of the American Rocket Society, the Tullahoma Section of the IAS toured the testing facilities of the Redstone Arsenal at Huntsville on October 22.

Highlights of the tour included demonstrations of the Nike guided missile control system and launching procedures for both the Nike and Corporal missiles. Inspection of the rocket test stands currently under construction was interesting and informative. Equally interesting were the various climatic test stands used to develop the propellants suitable for operation under adverse field conditions.

Of spectacular interest was the firing of aircraft-type rockets from a JATO accelerated sled.

ERNEST A. SANLORENZO, *Secretary*

Tulsa Section

The newly organized Tulsa Section held its first regular meeting October

More than 200 members and guests attended the confidential meeting of the St. Louis Section October 26 to hear a discussion of the flying qualities of jet fighters by test pilots representing the Air Force, Navy, and NACA. This is a partial view of the audience.

About 45 members of the IAS Tullahoma Section and the American Rocket Society visited Redstone Arsenal, Huntsville, Ala., for a conducted tour of the testing facilities.

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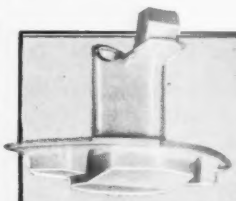

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11. Officers were elected as follows: Chairman, Clark L. Marks; Vice-Chairman, Everett W. Garrison; Recording Secretary, Gertrude Hill Fila; Corresponding Secretary, Richard M. Gilmore; and Treasurer, Robert B. Jenny.

Nineteen members and four visitors attended the meeting. Formation of the Tulsa Section was reported in Tulsa and Oklahoma City newspapers, and prospective members are being recruited in the local aircraft plants.

Chairman Marks appointed the following committees:

Program Committee: Ladislaus J. Fila, Chairman; Robert C. Curry, Roscoe R. Reagan, Curtis L. Logsdon, and Dale L. Hannaford.

Membership Committee: Franklin E. Peake, Chairman; Samuel G. Weir, Raymond Reilly, and Barton Kelly.

Student Activity Committee: Charles S. Hughes, Chairman; W. E. Spearman, Edward H. Raiguel, and James R. Sorem.

Public Relations Committee: Martin Graw, Chairman, and Bruce D. Olson.

RICHARD M. GILMORE
Corresponding Secretary

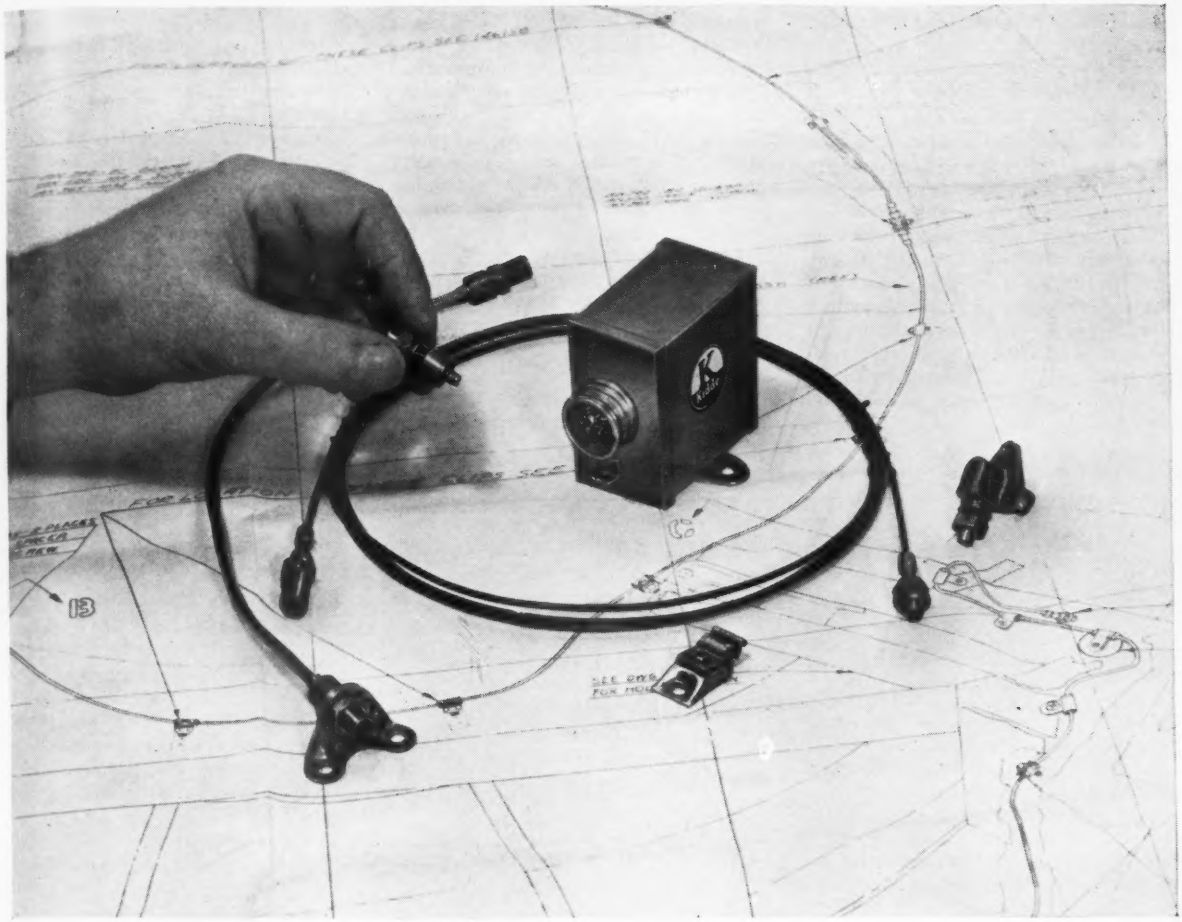
Mission of SAC

Twin Cities Section

Forty members and guests attended the first fall session of the Twin Cities Section September 15. After welcoming old and new members, Chairman Robert Hoel introduced the Section officers and briefly reviewed the program for the remainder of the current season. He then yielded the floor to Rudolf Hermann, Vice-Chairman, who introduced the speaker of the evening.

Major John H. Combs, USAF, of the Future Programs Branch of the Directorate of Plans at SAC Headquarters, spoke on "The Mission of the Strategic Air Command." He said that the primary mission of SAC was to maintain the peace by serving as a deterrent to enemy forces. The present Strategic Air Command with its jet aircraft, highly trained personnel, and nuclear weapons is the most powerful striking force in the world today. One present-day nuclear bomb, for instance, is capable of doing more damage than that done by the entire Eighth Air Force during World War II.

The SAC is essentially an air force within an air force, having a completely integrated command. It consists of 54 wings which are mostly bombardment groups, although SAC has its own support aircraft. This includes 1,500 combat-ready B-47 bombers. The Command has a military force of 130,000 and employs 15,000 civilians. The annual budget for equipping and



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Consisting essentially of a heat-sensing element and a transistor-triggered control unit, the Kidde Aircraft Fire Detector is the first to give both an immediate nacelle overheat danger signal and a fire alarm when temperature reaches a critical degree. Its hermetically-sealed control unit needs no shock or vibration isolation, has no vacuum tubes, and the entire unit requires no resetting after a fire. Here's how it works:

Located in the engine nacelle, the fire-sensing element—a long, wire-like unit—transmits nacelle temperature changes to the control unit, which is pre-set so as to remain on standby throughout the normal nacelle temperature range.

When the nacelle temperature rises above maximum normal, the control unit recognizes "potential trouble," and triggers an ABNORMAL TEMPERATURE signal.

However, if there is a sudden flash of fire in the nacelle, the control unit interprets the *rapid* rise in temperature as a definite danger condition, and a FIRE ALARM is actuated. The pilot then operates the nacelle fire extinguishing system to put out the blaze.

During any gradual temperature rise above maximum normal, the ABNORMAL TEMPERATURE signal remains operative all through the rise, and is replaced by the FIRE ALARM when a predetermined fixed fire temperature has been reached.

Lightweight and compact, the Kidde Aircraft Fire Detector can be adapted to meet the needs of all aircraft produced today. For more information, write Kidde now.

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maintaining this force is $850 million. It operates from a number of bases all around the world, although the Command Headquarters is located in Omaha, Neb.

In the event of impending attack, an alert would be sent to all SAC outposts. Since these units are maintained combat-ready at all times, a short warning would suffice. When the attack was imminent, SAC would launch its own counterattack. The initial strike would be made against enemy air bases to deny the enemy a return base. Subsequent attacks would be made on enemy industrial and military installations. By this means, the aggressor nation would be quickly disarmed and thus lose its power to strike effectively, probably in a period of less than 30 days.

We now have the power to disarm an enemy nation. We must continue to hold the lead by technological superiority and by maintaining adequate forces. The strategy has been carefully planned so that the cost of equipping these forces can be programed over a period of years. In effect, we are paying for the next war now.

The Strategic Air Command must be ready for war at any time. This endless readiness can guarantee the longest peace or the shortest war that the world has ever seen.

H. C. JOHNSON
Recording Secretary

Chuck Wooldridge, another senior related his experiences at Cessna Aircraft Company in Wichita, Kan. He summarized his work and told of some of the problems that he experienced. Chuck also told us about some of the misfortunes which befell the T-37 prototypes Cessna was flight testing while he was there. He was assigned to a fuel systems group which was working on the T-37.

The last speaker, Jim Iverson, a senior, reviewed his job at Convair in Fort Worth. While at Convair Jim was assigned to a performance group in the aerodynamics section. He worked on B-58 bombers and B-36 bombers which had been equipped to carry fighters.

ROBERT DIGHTON, *Secretary*

STUDENT BRANCHES

Agricultural & Mechanical College of Texas

W. R. Horsley, Head of the College Placement Office, spoke at the October 11 meeting of the Student Branch. Robert C. Barlow presided.

Mr. Horsley discussed employment possibilities, with particular reference to the aircraft industry. The main difficulty facing a graduate, he said, is to select the job best suited to him. As aids in evaluating job offers, he listed the following criteria: type of work, technical facilities, opportunities for graduate study and advancement, com pany's reputation, provisions of the training program, salary, job security, employee benefits, cost of living in the company's area, and various personal considerations.

At the business meeting, Charles R. Harris was elected Senior Representative and W. R. Ratcliff Junior Representative to the Engineers' Council.

HARLESS R. BENTHUL, *Secretary*

Georgia Institute of Technology

Sixty-one members attended the first fall meeting of the Student Branch held October 17 in the Aeronautical Engineering Building. Chairman Roland Fuentes introduced the officers. John J. Harper, Faculty Adviser, gave a short talk on the advantages of being a member of the Student Branch of the IAS.

Chairman Fuentes brought up for discussion a proposal by Arnold L. Ducoffe, Chairman of the Atlanta Section, that the annual Southeastern Student Paper Competition be held in Atlanta permanently because of its central location. The conference would be cosponsored by the Atlanta Section of IAS and a member school in the Southeast, a different school serving as cosponsor each year.

This plan will take effect only if all the schools involved vote to accept it. After a short discussion, the proposal was accepted unanimously by the Georgia Tech Student Branch.

ROBERT E. DROWNS, *Secretary*

Iowa State College

The September 28 meeting in Marston Hall was called to order by Chairman Arden Boyd, with 32 members and guests present.

Harold Ream was elected Chairman of the Student Branch's booth at the Engineering Carnival. Then several aeronautical engineering students who had been working in the aircraft industry during the summer related their experiences.

Dennis Holstein, a junior, described the job he held during the summer months with The Glenn L. Martin Company in Baltimore. He was assigned to the weights group working on the Matador guided missile.

Jack Dungan, a senior, told of his experiences while working for the Douglas Aircraft Company in Santa Monica, Calif. He worked on an optimum delta-wing model and gained experience with electronic computing equipment in the process.

The third speaker, William Kieffe, also a senior, was employed by Allison Division of General Motors in Indianapolis. He was associated with a test operations group which was running tests on the J-71 jet engine. He explained the construction and operation of a jet-engine test cell.

Reactivated!

Louisiana State University

On October 18, at 7 p.m., ten L.S.U. engineering students met in the Steam Lab building. The purpose of this meeting was to consolidate their ideas regarding the design and construction of a machine. The machine was to be powerful enough to motivate themselves and many others on this campus toward national recognition as enthusiastic potential engineers.

An estimate of the initial cost and the upkeep of such a machine was agreed upon. With many details still to be worked out, the meeting was adjourned for 1 week.

The machine in question was not to be the type usually associated with the field of engineering. It was to be operated on a mixture of zeal and initiative and lubricated by congenial and unselfish members whose characters would determine its capacity and endurance. This was to be the Student Branch of the Institute of the Aeronautical Sciences at L.S.U.

The ten students who attended the preliminary conference were Arturo Freyer, James Grethe, Rene Riviere, Samuel LeBlanc, Lloyd LeBlanc, Lawrence Freeman, Charles Burlo, John Gardner, Charles Statum, and Rudolph Begault. With the help of Associate Professor Ernest E. Maser, plans for the organization meeting were noised about the campus and prospective members were buttonholed.

On October 25, 17 engineering students cast their ballots, electing the following officers: Chairman, Lloyd P. LeBlanc; Vice-Chairman, John L. Gardner, Jr.; and Secretary-Treasurer, Rudolph A. Begault.

Professor Maser was chosen Faculty Adviser. He spoke briefly on the annual regional conference which affords student members an opportunity to present their original technical papers

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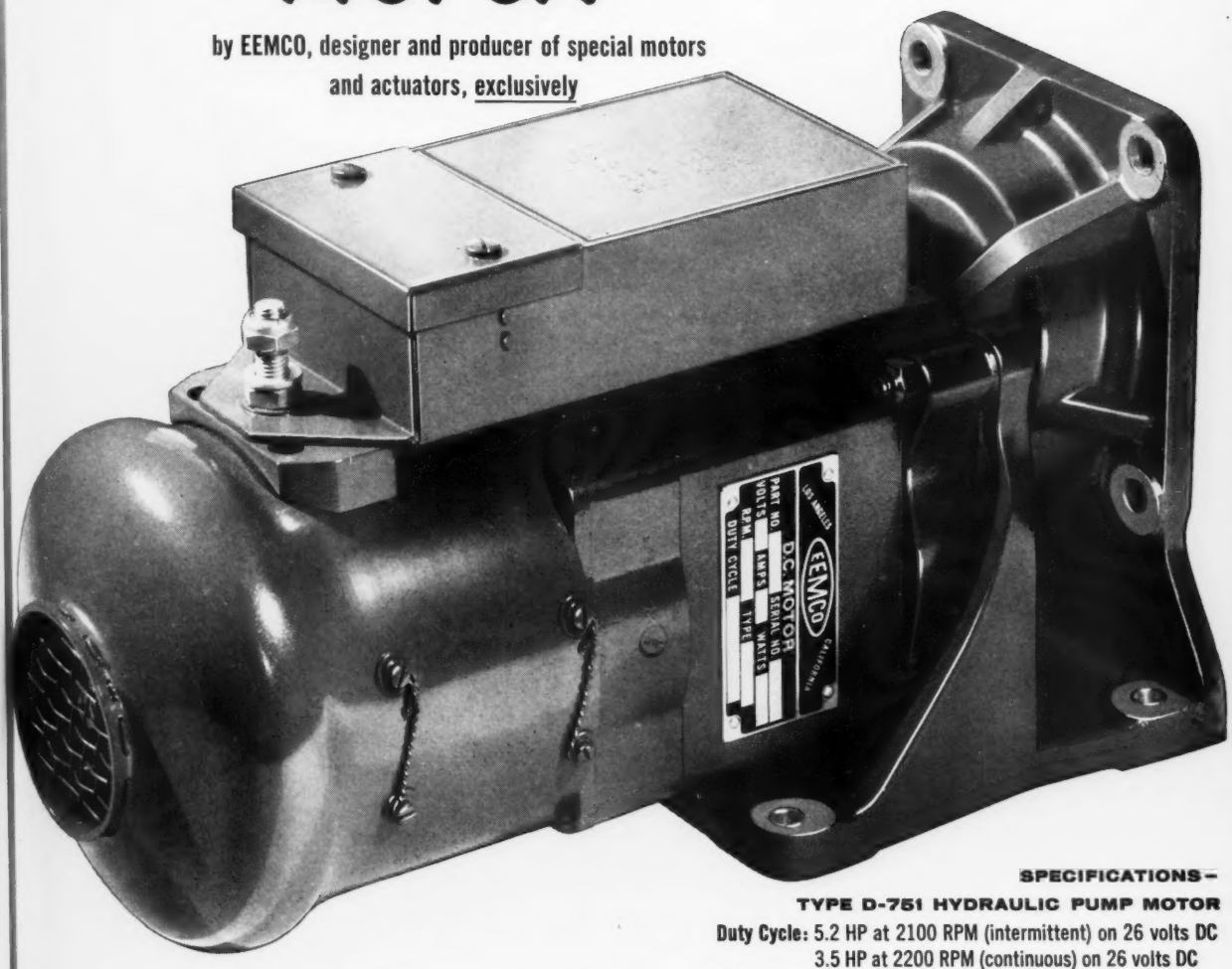

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in competition. Students present at this second meeting, besides the three officers, were Murrell J. Baxter, Charles Burlo, Jack Burthe, Gerald C. Coleman, Leroy C. Cuney, Lawrence J. Freeman, Arturo E. Freyer, Samuel J. LeBlanc, George E. Muller, Rene R. Riviere, Charles L. Statum, J. C. Miller, and D. P. Lester.

The IAS Student Branch was founded at L.S.U. in 1935, but because of comparatively small enrollment in the College of Aeronautical Engineering its activities were limited. In the past few years, organized meetings had been discontinued.

RUDOLPH A. BEGAULT
Secretary-Treasurer

North Carolina State College

All aeronautical engineering students were invited to attend the first fall meeting of the Student Branch on October 11. Chairman David Gurley opened the session with a short talk on the purpose and objectives of the IAS for the benefit of the nonmembers. Robert M. Pinkerton, Professor of Aeronautical Engineering, then spoke on the growth of aviation and the continual need for more engineers.

A committee was appointed to arrange for participation of the Aeronautical Engineering Department in the Engineers' Fair, scheduled for April. Possible exhibits were discussed, and plans were shown for a scale model of the Convair B-36 heavy bomber. The response to this proposed project was good. The students intend to build a model with a 7-ft. wing span.

The meeting closed with a tour of the Aeronautical Laboratory and Design Section for benefit of the lower classmen. Interest seemed to center on the wind tunnel and the Link trainer, both of which were in operation. Thirty-one new students indicated their desire to become members of the IAS.

KEITH E. VERBLE, *Secretary*

The Pennsylvania State University

Sixty engineering students attended the October 19 meeting. Chairman James Tedeschi introduced Dr. Hipsh, Head of the Aeronautical Engineering Department at Penn State, who spoke on "Nuclear-Powered Aircraft."

Dr. Hipsh opened his talk by stressing the importance of obtaining atomic power for airplanes. Then he explained the basic physics of atomic reactions involved and how the air-borne reactor would transmit its power to propulsion units. He discussed some current problems regarding nuclear power.

JCEL PETERSON, *Secretary*

Polytechnic Institute of Brooklyn

At the first meeting on October 12, new officers were installed and plans for the coming year were discussed. There is a record membership of over 100 students enrolled in the IAS this year. The new officers are: John Helgeson, Chairman; Frank Schlee, Vice-Chairman; Russel Marchefka, Treasurer; Robert Capria, Corresponding Secretary; and Howard Baum, Recording Secretary.

During the October 26 meeting, it was announced that there would be a field trip to The Glenn L. Martin plant in Baltimore on December 2. A film, *The Boeing 707*, was shown.

HOWARD BAUM
Recording Secretary

Purdue University

Eighty student members and guests heard a talk by Jorgen Jensen, Head of the Celestial Mechanics Section of The Glenn L. Martin Company, Baltimore. His topic was "Problems Encountered in Creating an Earth's Satellite." Mr. Jensen described some of the fundamental problems which have arisen in connection with the much publicized earth satellite. The talk was concluded with a question-and-answer period and

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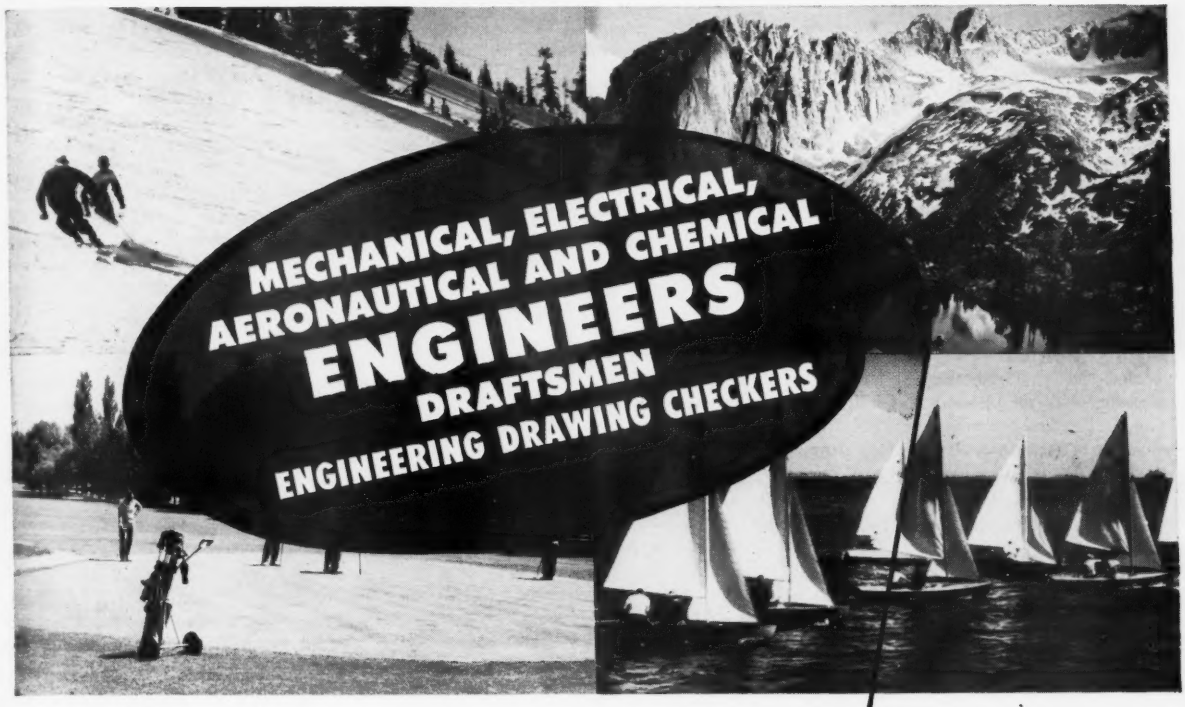

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the showing of Martin's film, *Horizons Unlimited.*

▶ Charles E. Jackson, Structural Dynamics Unit Chief, Boeing Airplane Company, Wichita, Kan., addressed 39 student members on October 25, on "Various Dynamics Problems That Have Been Encountered in Industry."

He told of special problems encountered in the design of present-day aircraft and the methods used in the solution of these problems. Mr. Jackson concluded his talk with a Boeing flutter model film.

▶ Forty-seven student members attended the first meeting of the fall semester on October 11. Chairman Lionel Wilson presented a tentative schedule of speakers and films for future meetings. The film *Design for Flying* was shown.

WILLIAM R. LONG, *Secretary*

U.S. Naval Postgraduate School

Milton U. Clauser, Director of the Aeronautical Research Laboratory of Ramo-Wooldridge Corporation, spoke at the Student Branch meeting October 12. The lecture was classified "secret."

The large turnout of nearly 100 members and guests demonstrated great interest in Dr. Clauser's subject. A vigorous question-and-answer period followed.

FRED S. DUNNING
Corresponding Secretary

University of Illinois

The Student Branch held its second meeting of the season October 25, in the Engineering Building, with Jim Piechocki in the chair.

Harry H. Hilton, Faculty Adviser, introduced the speaker, C. E. Jackson, Chief of Structural Dynamics of Boeing Airplane Company, Wichita, Kan.

Mr. Jackson's topic was "Dynamic Problems Encountered in Industry." He gave a brief "history" of the phenomenon of flutter, stating that it was first encountered by the Germans in World War I but that it was not until 1940, when Küssner's work was published, that any workable equations were available. The complexity of flutter analysis was emphasized and the need for and uses of electronic computers were stated. Because of the complexity of these high-powered analyses, Mr. Jackson said that, in the past, scaled-down elastic models were largely relied upon for design information. In some recent cases, however, the predictions from these models have not been too good, and they are being checked with electronic computers. He also spoke of actual cases concerning Boeing's jet bombers when flutter and gust loading problems were solved only when engineers went out in the field and used trial-and-error methods of correction.

Mr. Jackson's talk was followed by Boeing films on wind-tunnel testing of scaled elastic models.

▶ The first meeting of the Student Branch was held October 12 with 136 members attending. Jim Piechocki opened the meeting by explaining the functions and benefits of the IAS.

The following new officers were elected: Chairman, James J. Piechocki; Vice-Chairman, Joseph J. Voda; Secretary, Robert J. Shanahan; and Treasurer, Russell H. Hopps. Louis Oling was elected Engineering Council Representative and will assist John W. Kistenbroker, returning Representative.

Jim Piechocki then introduced the speaker, Harry H. Hilton, IAS Faculty Adviser and Associate Professor of Aeronautical Engineering, who spoke on "High Temperature Problems in Modern Aircraft Structures." Dr. Hilton told of the structural design problems resulting from both aerodynamic heating and heating of structures from jet blasts. With the aid of illustrative slides, he discussed the effect heating has on basic material properties such as the shearing modulus and various strengths. He spoke on the advantages and disadvantages of evaporative cooling and various types of insulation. The problems of thermal stresses and creep buckling at elevated temperatures were also discussed. Dr. Hilton closed by saying that, although the stress analyst would like to have more rigorous treatments of these problems, he must now rely to some degree on common sense and good engineering judgment because, world affairs as they are, "the planes have to fly."

ROBERT J. SHANAHAN, *Secretary*

University of Maryland

Jack R. Crowder, Supervisor of the Flight Controls Section of the Navy Bureau of Aeronautics, Washington, D.C., spoke on "Helicopter Flight Controls" at the October 18 meeting of the Student Branch. He discussed the principles of helicopter flight and the control and stability problems involved. The talk was supplemented by a Shell Oil Company film entitled *History of the Helicopter.*

Charles Stouffer presided at the meeting. A principal topic of discussion was the newly formed Mid-Atlantic Conference, which will meet here April 13, 14.

H. E. HUNTER, *Secretary*

University of Michigan

The meeting of October 18 was called to order by Chairman Robert Lauer, who outlined the coming semester's activities to the 60 students present.

The speaker of the evening was John W. Luecht, MIAS, Head of Analytical Design, Guided Missile Branch, Chrysler Corporation, Detroit. Mr. Luecht, a former Professor of our Aeronautical Engineering Department, explained the factors governing rocket and satellite flight. He compared solid propellants and liquid propellants as power sources for the three-stage rockets of the future. He discussed problems involved in staging or controlling satellite flight and the aerodynamics of rocket flight. A film on the Viking rocket was shown.

The meeting closed with 30 new members signing up.

ROBERT R. JONES, *Secretary*

Air-Borne Carriers

University of Minnesota

The student members of IAS and several faculty members heard a talk on "Air-Borne Aircraft Carriers" given by Professor Ralph H. Upson at their October meeting.

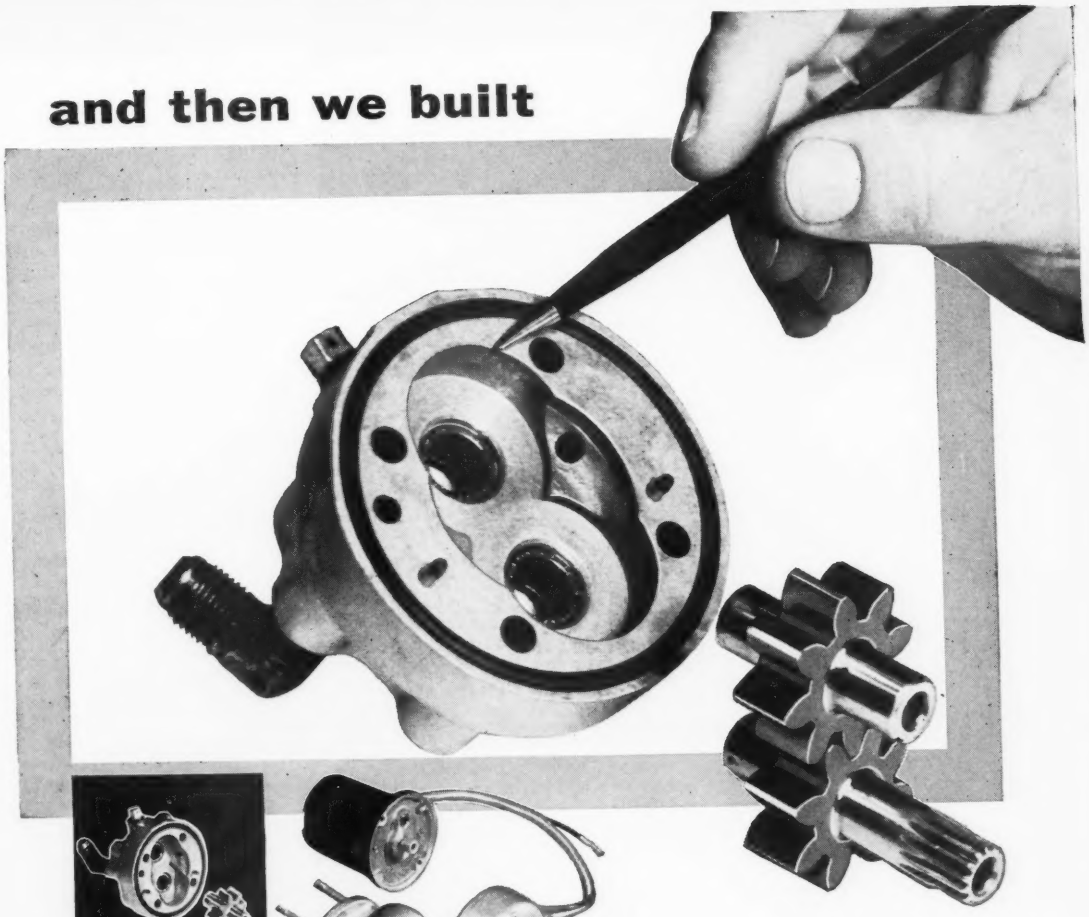
Professor Upson spoke on the relative merits of three types of aircraft carriers —lighter-than-air, heavier-than-air, and surface carriers. They were discussed and compared as to performance, dimensions, and endurance.

The advantages of the surface-type carrier are its tremendous carrying capacity, room for more complete maintenance, and practically unlimited endurance at low speed. The chief disadvantages are its relatively low speed, inability to go to altitude, and great size, making the ship unable to go through the Panama Canal. Also, there is the fact that there are so many "eggs in one basket" and if the carrier is destroyed during a battle so much is lost, while chances are not likely that the enemy would strike all of the equivalent carrier aircraft.

The advantages of the lighter-than-air ship are its ability to fly over land and to remain in the air for indefinite periods. The airship can hover with almost no expenditure of power while its parasite plane is in combat or while it is awaiting developments. Several such units can scatter or concentrate as events may dictate.

Professor Upson suggested the use of a metal-skinned airship filled with hydrogen. The metal skin would be a great fire preventive, he said. The metal would not be pierced by lightning. If there was a leak in the skin anywhere, the hydrogen would go out into the atmosphere rather than gathering between the outer and inner skin, as was the case with the fabric-covered dirigibles. With the consumption of fuel and the resultant decrease in weight, the excess hydrogen could be

and then we built



. . . a propeller pitch control transmission assembly for Beech Aircraft Corporation.

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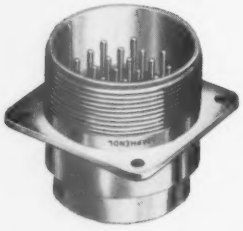

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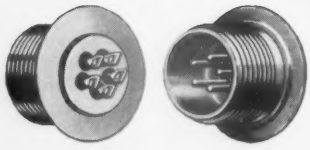

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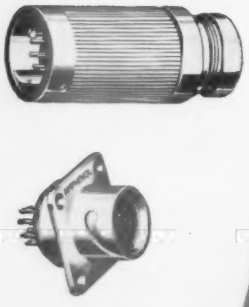

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burned to provide additional power. The lighter-than-air craft could carry a large plane suspended beneath the center of lift. Disadvantages of the dirigible are relatively low speed and no room for maintenance of the parasite airplane.

The heavier-than-air plane has the great advantage of a speed exceeding 400 knots. This would enable several of these aircraft, from all parts of the world, to assemble in the area where they were needed in a short time. The carrier could transport supersonic fighters that could not possibly have the range and endurance necessary, even when flown at subsonic speeds. The disadvantage of this type of carrier is its limited endurance of about 10 hours. If the airplane could be of the seaplane or amphibious type and could land on the water to await action, it would be almost unbeatable as a carrier.

The relative construction costs of the three carrier types are approximately the same per pound of aircraft carried, but the operational costs of the three may differ greatly

MARY JANE JUNG, *Secretary*

University of Notre Dame

The second fall meeting on October 27 was called to order by Chairman Joseph P. Poynton, with 35 present.

Dave Austgen, the present Engineering Advisory Board Representative, suggested that the new representative be elected near the middle of the fall semester instead of in January, so that he could attend a few meetings and become familiar with his duties. It was decided to elect the new representative at the next meeting.

The Chairman proposed that refreshments after the meetings be discontinued so that money could be conserved for the Student Branch treasury. This proposal was brought to a vote and passed.

The Chairman asked for suggestions on places of interest for a field trip. Among the tour objectives discussed were the Lewis Flight Propulsion Laboratory, NACA, in Cleveland; Wright-Patterson AFB, Dayton, Ohio; the Bendix Aviation Corporation plant in South Bend, Ind.; and Argonne National Laboratory, AEC, near Chicago.

It was announced that Patrick T. Chiarito, of the NACA, would speak at the November 17 meeting.

The Mardi Gras was discussed, and the Chairman made a brief talk on the duties of the booth chairman, such as the design and construction of the booth, and asked for volunteers.

RAYMOND J. MAUREN, *Secretary*

University of Oklahoma

Phil Fisher presided at the November 1 meeting, which was attended by 30 members and guests. The speaker was E. L. Zeiller, Aerophysics Group Engineer of Convair, A Division of General Dynamics Corporation. His talk was entitled, "A Discussion of Stability and Control with Special Reference to the B-36 Airplane." Mimeographed notes outlining the talk were distributed among the audience. The discussion following the talk was led by J. L. Hicks of Convair's Power Plant Group.

Greg Hosterman was appointed Social Chairman. He promised entertainment for future meetings from some of the sororities on the campus.

There was some discussion about preparing a display for the Engineering Open House next spring. In the past, it was pointed out, planning was usually put off until the last minute.

THOMAS B. SHOEBOTHAM, *Secretary*

University of Southern California

At the season's first meeting on October 10, the following officers were elected: Chairman, Dave Russell; Vice-Chairman, Raphael Wofe; Treasurer, Mike Hall; Secretary, Gilbert Herrera. Jerry Detwiler was named to handle publicity.

It was agreed to meet every Monday. Discussion showed that the members preferred speakers, movies, and field trips, in that order.

Two films were shown. The first, *Flutter of Elastic Models*, illustrated how flutter and vibration vary with position of the nacelle. The second, *Douglas Skyray Speed Run*, showed the preparations and flight of the Navy's delta-wing F4D in setting a world's speed record.

GILBERT HERRERA, *Secretary*

University of Texas

The first fall meeting of the Student Branch was held October 3 in the Experimental Science Building for the announced purpose of introducing freshman students to the IAS.

Chairman Ardean Wood called the meeting to order and explained the many benefits that can be derived from IAS membership. He then introduced the IAS Student Branch officers and the faculty members of the Aeronautical Engineering Department. M. J. Thompson, Faculty Adviser, urged the new students to participate in IAS activities.

Gene Wadsworth asked those interested to sign up for the intramural touch football team. Three motion pictures were shown through courtesy of North American Aviation, Inc., and the IAS.

WALTER MELTON, *Recording Secretary*

University of Virginia

Twenty-five members registered at the first meeting of the Student Branch October 13. This was almost double the active membership of last year.

The feature of the evening was a talk and film presented by S. Walter Hixon, Jr., Director of Training for the NACA Laboratory at Langley Field, Va. Following the color film concerning work carried on by the NACA, Mr. Hixon outlined the overall activities and responsibilities of the Ames, Langley, and Lewis laboratories.

Mr. Hixon brought out the fact that the quantity of research at all three laboratories is being increased in the field of aerothermodynamics. This includes the effects of supersonic and hypersonic flows on the surface temperature of bodies within the flows and naturally brings in research on structures to resist such elevated temperatures, both for the airplane or missile and for the propulsion device. One portion of the film showed the nose of a metal model actually melting as a result of ultra-high-speed flow in a wind tunnel.

Discussion after the film centered around the several wind-tunnel models Mr. Hixon had brought with him and the research that had been done using these models. One 10-in. metal model was valued at $1,000, and others were samples of fiberglass and plastic construction for force, pressure, and flutter testing. Mr. Hixon also elaborated on the recently announced "area rule" developed at NACA-Langley.

Chairman Jaime Alexander appointed a committee to investigate the possibilities of a fall field trip to some nearby aeronautical firm. Mr. Hixon extended an invitation to the Branch to attend the Triennial Inspection to be held at Langley Laboratory next spring.

It was decided that the Branch as a group would inspect the University of Virginia Airport. This will be done because the average aeronautical student never sees the airport until his fourth year when he begins his flight testing laboratory. The Mechanical Engineering Department has owned several airplanes in recent years, including an L-5, an L-13, and now a Stinson "Station Wagon" 4-place airplane which is used in flight- and engine-test programs. Most recent acquisition is a twin-engined Beech executive-type airplane which is owned by the University. All operate from the University of Virginia Airport at Milton, Va.

ALLAN D. SUMMERS, *Secretary*

University of Washington

In Guggenheim auditorium on the evening of October 19, approximately 60 IAS members and their wives were treated to a play entitled *A Wing Is Born*. The play covered the stress design of the Boeing KC-135 wing and was presented entirely by members of Boeing's KC-135 stress group.

Chairman, Bud Nelson opened the meeting by introducing Chet Weikel, aeronautical engineering lecturer and faculty adviser for the IAS student members. Professor Weikel gave a brief rundown on the organizational structure of the Boeing stress group and the part each subgroup plays in the overall completion of a major project.

Dialogue in the play was mostly technical, interspersed with witty quips, such as a stress engineer's remark that "the wing of the KC-135 must first be a tank, and then a wing." Slides were shown covering the discussion on stage, thus enabling the audience to follow details of the wing construction. The play ended with the tape-recorded take-off roar of the KC-135.

Bob Wahlborg, stress wing group leader at Boeing, wrote, directed, and produced the play.

GILBERT LEE
Recording Secretary

University of Wichita

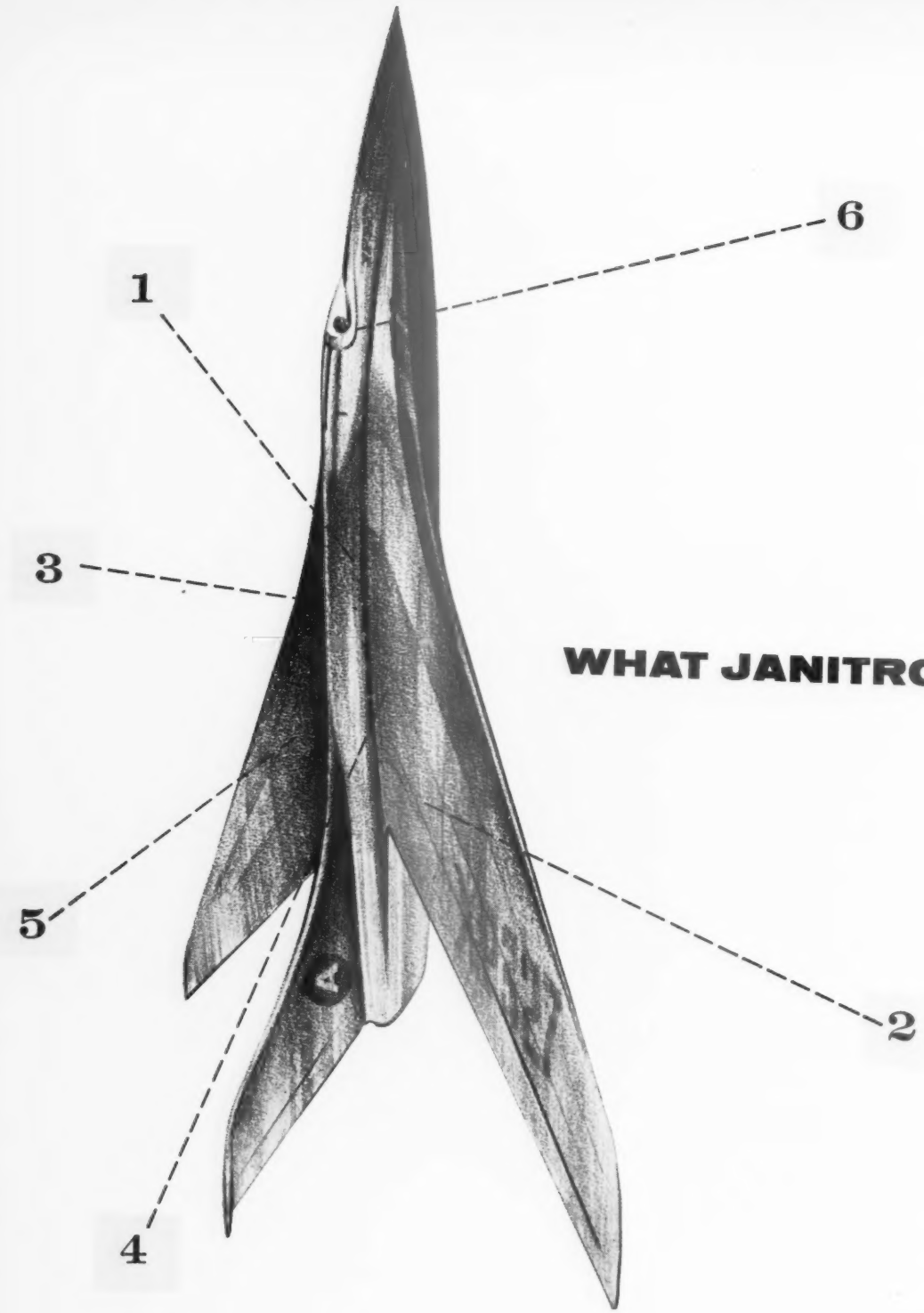
At the October 26 meeting, student members heard an address by Jerry Gordon of Beech Aircraft Corporation. Mr. Gordon discussed the Morane-Saulnier Paris, an executive-type jet plane which Beech Aircraft has demonstrated in this country.

Early in June the twin-jet, four-place Paris, built in France with the type designation MS-760, started a demonstration tour of the United States and Canada under sponsorship of the Beech Aircraft Corporation. In 90 days it carried 1,820 people. It made 724 demonstration flights from 38 different airports.

Its record of maintenance shows that less than 0.85 man-hours of maintenance time was required per hour of flight time for this 410-m.p.h. airplane. During the flight tests the Paris displayed excellent single-engine performance and stall characteristics.

Although the performance of this aircraft has been well established, Beech Aircraft has found little apparent demand for a commercial executive plane of this type at the price quoted. However, it is possible that the plane will have a military application as a primary jet training aircraft.

DUANE E. CHICHESTER, *Secretary*



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West Virginia University

At the November 2 meeting, Chairman Richard E. Walters introduced John F. Rentschler, a senior, who talked about his summer employment at the Columbus plant of North American Aviation, Inc. He described his duties in the Stress Section and the general routine at the factory. He offered several useful suggestions to those who had not yet worked in the aircraft industry; he said prospective summer workers would do well to investigate the possibility of living at a fraternity house.

Mr. Rentschler's talk was followed by a motion picture, *The Sperry Gyrosyn Compass*. This film traced the development of the compass from the first crude magnetic one through the gyroscope to the modern Gyrosyn. Disadvantages and advantages of the earlier compasses were demonstrated. Construction of the Gyrosyn was outlined. It was then shown in action beside a magnetic and a gyroscopic compass.

RAY HERRING
Corresponding Secretary

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Schoeffel M. F., Rear Adm. (Ret.), Dir.—Weapons Planning, General Precision Equipment Corp.

Transferred to Associate Fellow Grade

Morkovin, Mark V., Ph.D., Research Scientist & Lecturer in Aero., Johns Hopkins Univ.

Petrou, N. V., M.S. in E.E., Mgr., Devel. Engrg. Subdiv., Westinghouse Electric Corp. (Baltimore).

Elected to MEMBER Grade

Cahill, Jones F., B.S. in Ae.E., Sr. Aerodynamics Engr., Lockheed Aircraft Corp. (Marietta).

Carson, Joseph M., Jr., B.S. in C.E., Engr., Struct. Design Sect., Struct. Dept., The Glenn L. Martin Co.

Clark, Edward E., B. of Ae.E., Mgr., Aerodynamics Dept., The Glenn L. Martin Co.

Devries, John A., M.S. in M.E., Proj. Engr., Research Div., Curtiss-Wright Corp.

Farrar, Kenneth G., V-P & General Mgr., Douglas Aircraft Co., Inc. (Manhattan Beach).

Fifer, Stanley, Ph.D., Pres., Computing Center, Dian Laboratories, Inc.

Fleek, David N., Jr., B.S. in Ae.E., Proj. Engr., Allison Div., General Motors Corp.

Fleishman, Marvin M., B.S., Thermodynamics Proj. Engr., North American Aviation, Inc. (Los Angeles).

Fridell, Roland, B.M.E., Sales Engr., General Electric Co. (Washington, D.C.).

Goodwin, Joseph F., Engrg. Designer, Jet Propulsion Lab., California Institute of Technology.

Howard, Lee R., B.S.E.E., Flight Test Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Kraus, William P., Research Engr.—Missile R&D, Dept. 95-4, North American Aviation, Inc. (Downey).

McComas, William E., B.S.E.E., Consultant Engr., Member Tech. Staff, Digital System & Controls Dept., Hughes Aircraft Co.

Rempt, Henry, Electronics & Armament Staff Engr., Lockheed Aircraft Corp. (Burbank).

Ruling, F. Charles, A.B., Mgr., Aviation & Defense Industries Sales Dept., General Electric Co. (Schenectady).

Strickroth, Giles J., B.E.E., Mgr., Electronics Dept., Engrg. Div., The Glenn L. Martin Co.

Welch, Joseph D., M.S., Devel. Engr., Aero. & Ord. Div., General Electric Co. (Schenectady).

Wu, Jim H. T., M.A.Sc., Lecturer, Dept. of Mech. Engrg., McGill Univ. (Montreal).

Transferred to MEMBER Grade

Albanese, D. T., B.S. in Ae.E., Asst. Proj. Engr., Compressor Design Unit, Engrg. Div., Curtiss-Wright Corp

Beers, Henry S., Jr., M.S.E., Product Application Engr., Sales Engrg. Div., Curtiss-Wright Corp.

Bodofsky, Walter, B.S. (Aero.), Sr. Engr., Configurations Designer, Advanced Design Group, The Glenn L. Martin Co.

Bowyer, James M., Jr., M.S., Sr. Thermodynamics Engr., Engrg. Dept., Convair, San Diego, A Div. of General Dynamics Corp.

Carroll, Patrick C., M.S. in Ae.E., Aerodynamicist "A," Stability & Control Group, Tech. Sect., Ryan Aeronautical Co.

Clark, D. Gene, B.S.A.E., Pvt., U.S. Army; Chemical & Radiological Labs., Army Chemical Center.

Clayton, Richard M., Ens., Student, Aviation Electronics Officers School, USN.

Cooper, James P., B.S.M.E., Aerodynamicist, Proj. Engr., Aerodynamics Branch, Propeller Lab., WADC, Wright-Patterson AFB.

Fernandez, Constantino P., M.S. in Ae.E., Rep. of AF Contracting Officer, Lockheed Aircraft Corp. (New Mexico).

Fussell, Henry M., B.S., Asst. to Corporate Dir.—Military Sales, Lockheed Aircraft Corp. (Burbank).

Gustafson, Winthrop A., M.S. in Ae.E., Student—Aero. Engrg., Univ. of Illinois.

Hale, Roy E., Jr., B.S. in Ae.E., Capt., Supervising Computing Personnel, WADC.

Harkins, W. D., B.S. in Ae.E., Anti-Submarine Warfare Officer, USN (Weeksville).

Hayos, Fred G., M.S. in Aero., Thermodynamics Engr., Northrop Aircraft, Inc.

Koeppel, Samuel S., B. of Ae.E., Pfc., U.S. Army Ordnance Corps, Picatinny Arsenal (Dover).

Korkegi, R. H., Ph.D. in Ae.E., Research Assoc., Transonic & Supersonic Aircraft, Univ. of Southern California.

Louthan, John D., B.S., Lead Devel. Design Engr., Chance Vought Aircraft, Inc.

Moss, Harold M., M.S. in Ae.E., Prelim. Design Engr., Grumman Aircraft Engineering Corp.

Prigge, John S., Jr., A.E., Proj. Leader, D.I.C. Staff, Aero. Dept., Aerophysics Research Group, Massachusetts Institute of Technology.

Randall, Robert E., M.S. in Ae.E., Engr. III, Aro, Inc.

Rattinger, Ivan, M.Ae.E., Struct. Engr.—Analysis & Design, U.S. Army Chemical Center (Maryland).

Sauer, Robert C., B. of Ae.E., Sr. Engr., Group Leader—Helicopter RPM Control Devel., Sperry Gyroscope Co. Div. of Sperry Rand Corp.

Schoenheit, Albert E., B.S. in Ae.E., Aerodynamic Engr., North American Aviation, Inc. (Los Angeles).

Valluri, Sitaram R., Ph.D. in Aero., Research Fellow, Aero. Dept., California Institute of Technology.

Woodring, Diedrich F., B. of Ae.E., Aircraft Designer, Lockheed Aircraft Corp. (Marietta).

Elected to Associate Member Grade

Langhorst, Albert E., Marketing Service Training School, General Electric Co. (Cincinnati).

Transferred to Associate Member Grade

Wester, John F., S.M. in Ae.E., Lt Comdr., USN; Gunnery Officer, Staff Comdr. Fleet Air Hawaii, NAS.

Elected to Technical Member Grade

Burke, Thaddeous E., Hydraulic Engr., Lockheed Aircraft Corp. (Burbank).

Oza, Rohit, Chief Flight Engr., Air-India International.

Slanker, Earl J., B.S. in Ae.E., Asst. to V-P, Ryan Aeronautical Co.

Instrument System

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MODEL R-1

Williams, Ben W., Engrg. Drawings Checker "A," Douglas Aircraft Co., Inc. (Long Beach).

Transferred to Technical Member Grade

Bergquist, John C., B.S., Ens., USN; Aviation Trainee (Pilot), NAS (Pensacola).

Bowlby, Ronald L., B.S. in Ae.E., Assoc. Engr., The Glenn L. Martin Co.

Boyce, Frank J., B.S., Jr. Engr.—Aerodynamics, Douglas Aircraft Co., Inc. (Long Beach).

Brush, Ronald A., B.S. in Ae.E., Ens., USN; Student Naval Aviator, NAAS, Barin Field.

Campbell, Robert L., B.S., Aero. Engr. —Guided Missile Research, Motorola, Inc.

Campbell, Roy A., B.S. in Ae.E., 2nd Lt., USAF.

Cervellino, Lawrence J., B. of Ae.E., Struct. Flight Test Engr., Grumman Aircraft Engineering Corp.

Conway, Michael A., B.S. in Ae.E., Wind Tunnel Test Engr., McDonnell Aircraft Corp.

Cook, Charles E., Student, Purdue Univ.

Cook, James R., B.S.E., Flight Test Analyst, Lockheed Aircraft Corp. (Burbank).

Dalton, John D., Capt., USAF; R&D Staff Officer, Devel. Directorate, AF Special Weapons Center, Kirtland AFB.

Deibert, George H., Instrumentation Engr., Grumman Aircraft Engineering Corp.

Eberly, David K., B.S., Graduate Research Engr., Institute of Engrg. Research—Low Pressures, Univ. of California (Berkeley).

Eden, Robert J., Jr. Struct. Engr., Sikorsky Aircraft Co.

Erskine, David S., Jr. Engr.—Design, North American Aviation, Inc. (Los Angeles).

Farrell, William, B.A.E., Research Asst. & Graduate Student, Rensselaer Polytechnic Institute.

Frandsen, Niels P., B.S. in Ae.E., Aero. Engr. NOL (White Oak).

Gerhard, Harvey C., B.S. in Ae.E., Flight Test Engr., North American Aviation, Inc. (Columbus).

Godston, Joel, B.S. in Ae.E., Analytical Engr., Pratt & Whitney Aircraft Div., United Aircraft Corp.

Goldberg, Leon, B.A.E.

Grafton, Peter E., M.S. in C.E., Airframe Stress Engr., Missile Sect., Bendix Products Div., Bendix Aviation Corp.

Gray, Glenn M., B.A.E., Test Engr. "A," Piasecki Helicopter Corp.

Grove, Benjamin D., B.S. in Ae.E., Assoc. Engr., The Glenn L. Martin Co.

Hadzinski, Alexander, B.A.E., Assoc. Engr., Lockheed Aircraft Corp. (Burbank).

Hamilton, Harry D., B.S., Ens., USN; Student Pilot, NAS (Pensacola).

Hawk, Robert J., B. of Ae.E., Jr. Engr.—Struct., North American Aviation, Inc. (Columbus).

Hayes, Robert E., Jr. Engrg. Designer, North American Aviation, Inc. (Los Angeles).

Hefferman, Frank J., Capt., USAF; Asst. Chief, Northrop Branch, Dir.—Aircraft Hq., ADC, Ent AFB.

Herndon, Herbert F., B.S. in Ae.E., Ens., USN; Student Naval Aviator, Naval Air Base Training Command (Pensacola).

Hoover, Richard A., B.S. in Ae.E., Jr. Engr., Northrop Aircraft, Inc.

Kastner, Robert E., B. of Ae.E., Design Draftsman, Engrg. & Research A, Div. of ACF Industries.

Knerr, Roger M., Engr., McDonnell Aircraft Corp.

Kramer, Raymond M., B.S. in Ae.E., Assoc. Engr.—Aerodynamics, Lockheed Aircraft Corp. (Burbank).

Lane, Howard M., Major, USAF.

Latimer, M. Dale, B.S., Jr. Test Engr., Engrg. Test Lab., Convair, San Diego, A Div. of General Dynamics Corp.

Lemoine, Paul L., Jr. Aerodynamic Engr., North American Aviation, Inc. (Los Angeles).

Louie, Henry E., Jr. Design Engr., North American Aviation, Inc. (Los Angeles).

Mac Nicol, Robert K., B.S., Jr. Engr., Northrop Aircraft, Inc.

Marzella, Angelo F., Draftsman, Design Detail Group, Grumman Aircraft Engineering Corp.

Meyers, Everett E., B.S. in Ae.E.

Morton, Frank G., B.S. in Ae.E., Half-Time Graduate Asst., Univ. of Illinois.

Moulin, Gerald R., B.S. in Ae.E., Engr. "C," United Airlines, Inc. (San Francisco).

Pruden, Albert L., Jr., B.S.M.E. (Aero.), Lt., USAF.

Ray, Bernard F., B.S. in Ae.E., Engr., Basic Loads Group, Struct. Devel. Dept., Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Risdal, Ralph E., M.S., Assoc. Engr., Douglas Aircraft Co., Inc. (El Segundo).

Ross, Lee E., B.S., Test Engr., Boeing Airplane Co.

Ryan, Jerome D., Jr. Aero. Engr., Ryan Aeronautical Co.

Sater, Stanford J., B.A.E., 1st Lt., USAF; Aero. Engr., Kirtland AFB.

Sheport, John L., B.S., Asst. Flight Test Engr., McDonnell Aircraft Corp.

Simitses, George J., B. of Ae.E., Graduate Student & Part-Time Instructor, Georgia Institute of Technology.

Simmons, Robert A., Design Engr., Emerson Electric Manufacturing Co.

Stewart, Ward W., Jr. Engr., Pastushin Aviation Corp.

Stonum, George M., Layout Draftsman, Emerson Electric Manufacturing Co.

Thomas, Roger V., B.S., Jr. Weights Engr., North American Aviation, Inc. (Columbus).

Thomasson, Fred T., B.S. in Ae.E., Flight Test Engr., Grumman Aircraft Engineering Corp.

Turner, Kenneth L., B.M.E., Engrg. Intern, NACA (Langley AFB).

Voigt, Richard A., Engr., Shelly Associates.

Walker, Alpheus H., Jr., B.S. in Ae.E., Jr. Engr.—Aerodynamics, Missiles Div., McDonnell Aircraft Corp.

Webb, Philip E., B.S.E. (Aero.), Research Asst., Rocket Lab., Engrg. Research Institute, Univ. of Michigan.

Whitten, Robert P., B. of Ae.E.

Williamson, William J., Ae.E., Sr. Aerodynamics Engr., Marquardt Aircraft Co.

Wohlrab, Floyd J., Jr., B.S., Aerodynamicist, McDonnell Aircraft Corp.

Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

THIS SECTION reviews important periodicals, technical and research reports, and books received in the IAS Library in order to provide basic documentation for engineers and scientists.

INTERNATIONAL AERONAUTICAL ABSTRACTS, published as an insert in each issue, is an accelerated reviewing service covering world-wide scientific and technical literature. This work is performed by the IAS Staff and is supported by the Air Force Office of Scientific Research of the Air Research and Development Command.

A key to the abbreviations used for titles of periodicals and report series is published semiannually, in the January and July issues.

The AERONAUTICAL ENGINEERING INDEX, published since 1947, provides an annual cumulation of the materials reviewed in this section.

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Abbreviations for Titles of Periodicals and Reports

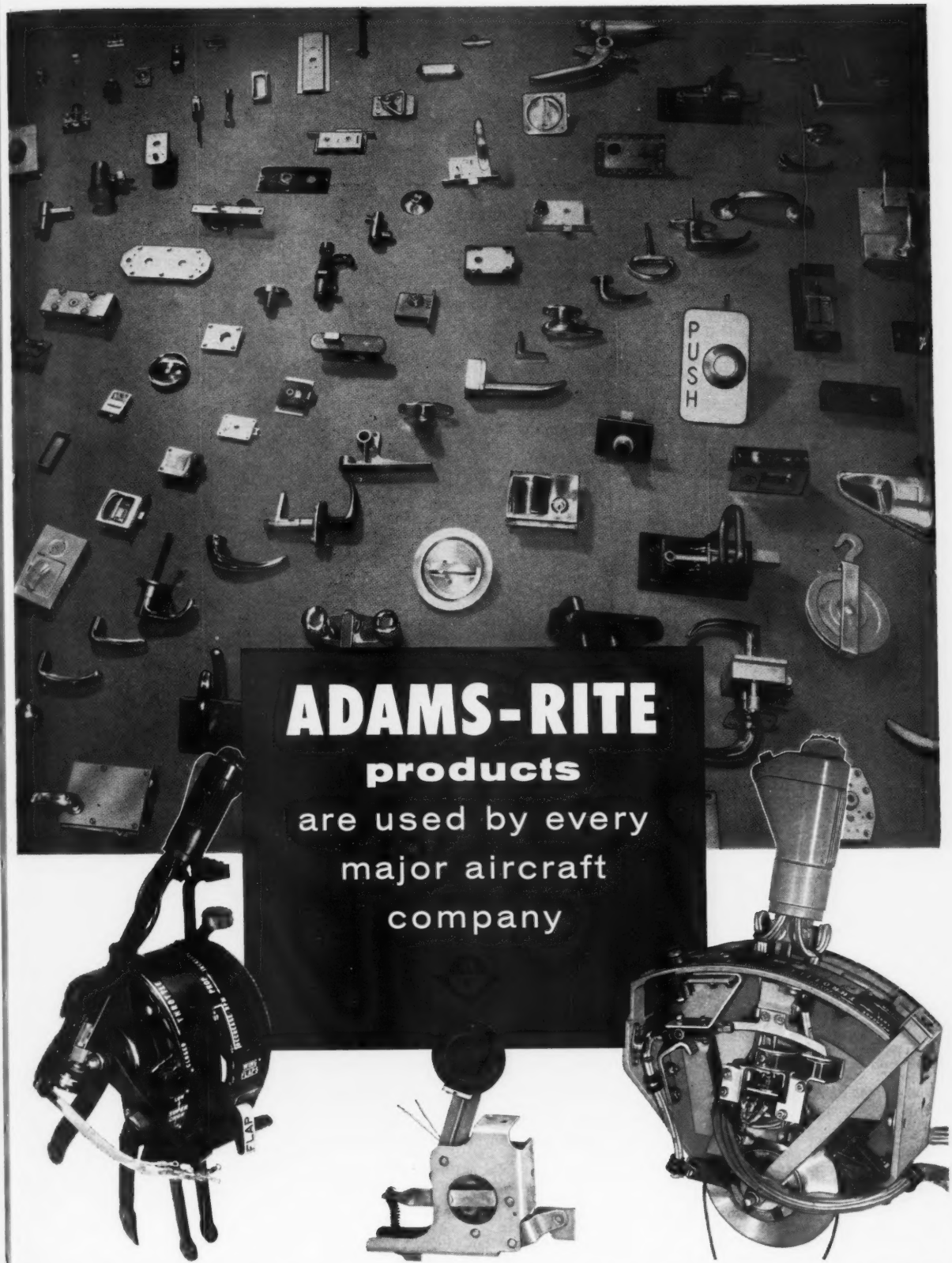
Titles of periodicals and reports cited in the Aeronautical Reviews Section are abbreviated in order to conserve space and to expedite the flow of materials. Selection of titles in this list of abbreviations is based on materials received during the past year. Reference citations are listed in the briefest form, however, giving full pagination for periodicals and the total number of pages for reports and other types of publications.

Publications reviewed are filed permanently in the IAS Library. Requests for loans of materials should be directed to the Librarian, IAS Library, 2 East 64 St., New York 21, N.Y.

A&M Coll. Tex. Eng. Exp. Sta. Res. Rep. Agricultural and Mechanical College of Texas, Texas Engineering Experiment Station, Research Report
Acta Polytechnica (Stockholm)
ADA Info. Bul.; Res. Rep. The Aluminium Development Association, Information Bulletin; Research Reports (London)
Aero Dig. Aero Digest
Aero. Argentine Commun. & Inform. Aeronautica Argentine, Communicación e Información
Aero. Eng. Rev. Aeronautical Engineering Review
Aero. Inst. Tech. Hochschule, Braunschweig, Bericht. Aerodynamisches Institut der Technischen Hochschule, Braunschweig, Bericht
Aero. Quart. The Aeronautical Quarterly
Aero Res. TN Bul. Aero Research Technical Note Bulletin
Aero-Rev. Aero-Revue (Switzerland)
Aero. Versuchsanstalt, Luftfahrtforschung, Bericht. Aerodynamischer Versuchsanstalt, Göttingen, Luftfahrtforschung, Bericht
Aeronautics
The Aeroplane
L'Aerotecnica (Rome)
Aerovox Res. Worker. Aerovox Research Worker
AHS Papers. American Helicopter Society, Papers
AIAA Papers. Aircraft Industries Association of America, Papers
AIEE Papers. American Institute of Electrical Engineers, Papers
Air Facts
Air Force
Air Line Pilot
Air Pictorial
Air Rev. Air Revue (Brussels)
Air Transp. Air Transportation
Air U. Quart. Rev. Air University Quarterly Review
Airborne Inst. Lab. Proj. Rep. Airborne Instruments Laboratory, Project Report
Aircraft (Australia)
Aircraft (Canada)
Aircraft Eng. Aircraft Engineering
Aircraft Heating Dig. Aircraft Heating Digest
Aircraft Prod. Aircraft Production
Airport Operators Council, Papers
Airports & Air Transp. Airports & Air Transportation
Allis-Chalmers Elec. Rev. Allis-Chalmers Electrical Review
ALPA Papers. Air Line Pilots Association, Papers
Aluminium (Düsseldorf)
Am. Av. American Aviation
Am. Engr. American Engineer
Am. Helicopter. American Helicopter
Am. J. of Phys. American Journal of Physics
An. Fis. Quim. Anales de Fisica y Quimica (Madrid)
An. Phys. Annalen der Physik (Leipzig)
An. Soc. Cientifica. Anales Sociedad Cientifica (Argentina)
An. Soc. Sci., Bruxelles. Annales de la Société Scientifique de Bruxelles
An. Télécomm. Annales des Télécommunications (Paris)
Anal. Chem. Analytical Chemistry
Antiaircraft J. Antiaircraft Journal
Appl. Hydraulics. Applied Hydraulics
Appl. Mech. Rev. Applied Mechanics Reviews
Appl. Sci. Res., Sect. A. Applied Scientific Research, Section A (Mechanics, Heat, Chemical Engineering, Mathematical Methods)
Appl. Sci. Res., Sect. B. Applied Scientific Research, Section B (Electrophysics, Acoustics, Optics, Mathematical Methods)
Arch. Budowy Maszyn. Archiwum Budowy Maszyn, Polska Akademia Nauk, Komitet Budowy Maszyn (Warsaw)
Arch. für Eisenhüttenwesen. Archiv für das Eisenhüttenwesen (Düsseldorf)
Arch. für Tech. Messen (Munich)
Arch. Mech. Stosowanej. Archiwum Mechaniki Stosowanej, Zakład Mechaniki Ośrodków Ciagłych Polskiej Akademii Nauk (Warsaw)
Argonne Natl. Lab. Rep. Argonne National Laboratory, Reports
ASCE Air Transp. Div. Papers; Preprints. American Society of Civil Engineers, Air Transport Division, Papers; Preprints
ASME Preprints; Papers. American Society of Mechanical Engineers, Preprints; Papers
ASTM Bul. American Society for Testing Materials, Bulletin
Astronautica Acta
Astronautics (Journal of the American Astronautical Society)
ATA Papers. Air Transport Association (of America), Papers
Atomes (Paris)
Audio
Australia, Aero. Res. Consultative Comm. Rep. Australia, Department of Supply, Aeronautical Research Consultative Committee, Reports
Australia, ARL ATM; EN; IN; Mech. Eng. TM; Notes; Rep.; S&M Monogr.; S&M TM. Australia, Department of Supply, Aeronautical Research Laboratories, Aerodynamics Technical Memorandum; Engines Notes; Instruments Notes; Mechanical Engineering Technical Memorandum; Notes; Reports; Structures and Materials Monographs; Structures and Materials Technical Memorandum
Australia, CSID Aero. Res. Rep. Australia, Council for Scientific and Industrial Research, Aeronautical Research Reports
Australia, CSIRO Radiophys. Lab. Rep. Australia, Commonwealth Scientific and Industrial Research Organization, Radiophysics Laboratory, Reports
Australian J. of Appl. Sci. Australian Journal of Applied Science
Australian J. Phys. Australian Journal of Physics [formerly Australian Journal of Scientific Research, Series A (Physical Sciences)]
Auto. Ind. Automotive Industries
Auto-Technik (Berlin)
Av. Age. Aviation Age
Av. Week. Aviation Week
Avia Vliegwereld (Netherlands)
Aviação (Rio de Janeiro)

Battelle Tech. Rev. Battelle Technical Review
Bearing Engr. Bearing Engineer
Bee Hive
Bell Aircraft Rep. Bell Aircraft Corporation, Reports
Bell System Tech. J. Bell System Technical Journal
Bendix Av. Eng. Rep. Bendix Aviation Corporation, Engineering Reports
Boeing Mag. Boeing Magazine
Braunschweig Tech. Hochschule Inst. Strömungsmech. Rep. Braunschweig Technische Hochschule Institut für Strömungsmechanik, Reports
Bristol Quart. The Bristol Quarterly
Brit. Aircraft Ind. Bul. British Aircraft Industry Bulletin
Brit. J. Appl. Phys. British Journal of Applied Physics
Brit. Welding J. British Welding Journal
Brown-Boveri Rev. Brown-Boveri Review
Brown U. Div. Eng., USAF TR. Brown University, Division of Engineering, United States Air Force, Technical Reports
Bul. Acad. Polonaise Sci. Bulletin de l'Academie Polonaise des Sciences (Warsaw)
Bul. AMS. Bulletin of the American Meteorological Society
Bul. Ass. Suisse Élec. Bulletin, Association Suisse des Électriciens (Zurich)
Bul. Serv. Tech. Aéro. Bulletin du Service Technique de l'Aéronautique (Brussels)
Bul. Soc. Française Élec. Bulletin, Société Française des Électriciens (Paris)
Bus. Flying. Business Flying

C. R. Acad. Sci., Paris. Compte Rendu de l'Académie des Sciences, Paris
CAHI Rep. Central Aero-Hydrodynamical Institute (Moscow), Reports
CAI Log. Canadian Aeronautical Institute, Log (Superseded by **Can. Aero. J.**)
Can. Aero. J. Canadian Aeronautical Journal
Can. Airline Pilot. Canadian Airline Pilot
Can. Av. Canadian Aviation
Can. J. Phys. Canadian Journal of Physics
Can. J. Tech. Canadian Journal of Technology
Canada, CARDE Misc. Rep. Canada, Canadian Armament Research and Development Establishment, Miscellaneous Reports



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CANADIAN—Railway & Power Engineering Co., Montreal. Offices throughout Canada.

Canada, Dept. Mines & Tech. Surveys Rep. Canada, Department of Mines and Technical Surveys, Reports
Canada, DRML Rep. Canada, Defence Research Medical Laboratories, Reports
Canada, NAE HSAL Rep. Canada, National Aeronautical Establishment, High Speed Aerodynamics Laboratory, Reports
Canada, NAE LR; Note; Quart. Bul.; Rep. Canada, National Aeronautical Establishment, Laboratory Report; Note; Quarterly Bulletin; Reports
Canada, NRC Div. Mech. Eng. Rep. Canada, National Research Council, Division of Mechanical Engineering, Reports
Canada, RCAF Rockcliffe, Rep. Canada, Royal Canadian Air Force, Rockcliffe, Reports
Carnegie Inst. Tech. TR. Carnegie Institute of Technology, Technical Reports
CEC Recordings
Cen. Sviluppo Transp. Aerei. Centro per lo Sviluppo dei Transporti Aerei (Rome)
Chartered Mech. Engr. The Chartered Mechanical Engineer (London)
Chrysler Eng. Div. Rep. Chrysler Corporation, Engineering Division, Reports
Ciampino (Interairport) (Rome)
CIT Hydrodynamics Lab. Rep. California Institute of Technology, Hydrodynamics Laboratory, Reports
CIT Jet Propulsion Lab. Prog. Rep. California Institute of Technology, Jet Propulsion Laboratory, Progress Reports
CIT Mech. Eng. Lab. Rep. California Institute of Technology, Mechanical Engineering Laboratory, Reports
CIT Paper; Rep. California Institute of Technology, Papers; Reports
Coll. of Aeronautics, Cranfield, Note; Rep. College of Aeronautics, Cranfield, England, Notes; Reports
Collins Signal
Columbia U. Inst. Air Flight Struc. AF TN. Columbia University, Institute of Air Flight Structures, Air Force Technical Notes
Commun. on Pure & Appl. Math. Communications on Pure and Applied Mathematics
Cook Res. Labs. Papers. Cook Research Laboratories, Papers
Cornell Aero. Lab. FRM; Rep.; Transl. Cornell Aeronautical Laboratory, Inc., Flight Research Memorandum; Reports; Translations
Cornell-Guggenheim Av. Safety Cen. Papers; Rep. Cornell-Guggenheim Aviation Safety Center, Papers; Reports
Cornell U. Med. Coll. Crash Injury Res. Papers. Cornell University Medical College, Crash Injury Research Papers
Corrosion
Curtiss-Wright Aero. Div. Rep. Curtiss-Wright Corporation, Wright Aeronautical Division, Reports

de Havilland Gazette
Dickinson Law Rev. Dickinson Law Review
Dokl. Akad. Nauk. Doklady Akademiia Nauk (Leningrad)
Douglas Rep. Douglas Aircraft Company, Inc., Reports
Douglas Serv. Douglas Service
DVL e.V., Flugtech. Fachgruppen Arbeitsgem., Ing. Ausbild. Abteil., Mitteil.; Tech. Berichte. Deutsche Versuchsanstalt Luftfahrt eingetragner Vereine, Flugtechnische Fachgruppen und Arbeitsgemeinschaften, Ingenieur Ausbildung Abteilung, (Berlin-Adlershof), Mitteilungen; Technische Berichte

Elec. Commun. Electrical Communication
Elec. Eng. Electrical Engineering
Elec. Mfg. Electrical Manufacturing
Electronic Eng. Electronic Engineering
Electronics
Electronics Forum. See **Proc. Inst. Electronics**
Elektrotech. Obz. Elektrotechnický Obzor (Prague)
L'Elettrotecnica (Milan)
Eng. J. Engineering Journal
The Engr. The Engineer
Engr. Dig. Engineer's Digest
Ericsson Rev. Ericsson Review (Stockholm)
Ericsson Tech. Ericsson Technics (Stockholm)
Escher Wyss News
Esso Air World
Esso Standard Oil Co. Rep. Esso Standard Oil Company, Reports
ETH Inst. für Aerodynamik Mitteilungen. Eidgenössische Technische Hochschule, Institut für Aerodynamik (Zurich), Mitteilungen

Fasteners
Flight
Flight Control (Bendix)
Flight Mag. Flight Magazine
Flight Safety Fn. Mech. Bul.; Papers. Flight Safety Foundation, Inc., Mechanics Bulletin; Papers
Flugwelt (Wiesbaden, Germany)
Flyg-och Navalmed. Nämnden, Medd. Flyg-och Navalmedicinska Nämnden (Stockholm), Meddelanden
Flying
Flying Safety (USAF). Flying Safety (United States Air Force)
Focke-Wulf Flugzeugbau GmbH, Bremen/Werkstoff-Versuchsabteilung, Tech. Berichte. Focke-Wulf Flugzeugbau, Gesellschaft mit beschränkter Haftung, Bremen/Werkstoff-Versuchsabteilung, Technische Berichte (Germany)
Foote Prints
Forschung Gebiete Ing., Mitteil. Forschung auf dem Gebiete des Ingenieurwesens (Berlin), Mitteilungen
FPS e.V. Mitteil. Forschungsinstitut für Physik der Strahlantriebe, eingetragner Vereine (Stuttgart), Mitteilungen
France, Min. de l'Air BST; NT; PST. France, Ministère de l'Air, Bulletin des Services Techniques; Notes Techniques; Publications Scientifiques et Techniques
France, Min. des Travaux Publics, Transp. et Tourisme, Bul. Liaison et Doc. du Sec. Gén. Av. Civ. et Com. France, Ministère des Travaux Publics, des Transports et du Tourisme, Bulletin de Liaison et de Documentation du Secrétariat Général à l'Aviation Civile et Commerciale
France, ONERA Pubs. France, Office National d'Études et de Recherches Aéronautiques, Publications
Franklin Inst. Labs. TR. Franklin Institute Laboratories for Research and Development, Technical Reports
French Acad. Devel. Aero. Res. & Aero. Tech. Serv. Rep. French Academy for the Development of Aeronautical Research and Aeronautical Technical Service, Reports
French Comm. Devel. Aero. Res. TN. French Committee for the Development of Aeronautical Research, Technical Notes
The Frontier
Fulmer Res. Inst. Rep. Fulmer Research Institute Limited, Reports

GALCIT Memo.; TR. Guggenheim Aeronautical Laboratory, California Institute of Technology, Pasadena, Calif., Memorandums; Technical Reports
Garbell Res. Foundation, Aero. Ser. Garbell Research Foundation, Aeronautical Series
G-E Rev. General Electric Review
Gen. Radio Exp. General Radio Experimenter
Ges. d. Wiss. Göttingen, Nach, a. d. Math. Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse, Nachrichten aus der Mathematik (Germany)
GFW Forschungsreihe, Bericht. Gesellschaft für Weltraumforschung, Forschungsreihe, Bericht (Stuttgart, Germany)
GM Eng. J. General Motors Engineering Journal
Goodyear Aircraft Corp. Rep. Goodyear Aircraft Corporation, Reports
Gt. Brit., AAEE Rep. Great Britain, Aeroplane and Armament Experimental Establishment, Boscombe Down, Reports
Gt. Brit., AERE Rep. Great Britain, Atomic Energy Research Establishment, Reports
Gt. Brit., ARC CP. Great Britain, Aeronautical Research Council, Current Papers
Gt. Brit., ARC R&M. Great Britain, Aeronautical Research Council, Reports & Memoranda
Gt. Brit., DSIR FPR Bul. Great Britain, Department of Scientific & Industrial Research, Forest Products Research Bulletin
Gt. Brit., MAEE Rep. Great Britain, Marine Aircraft Experimental Establishment, Reports
Gt. Brit., Meteorological Off. Prof. Notes & Reps. Great Britain, Meteorological Office, Professional Notes and Reports
Gt. Brit., Min. Transp. & Civil Av. Rep. Great Britain, Ministry of Transport and Civil Aviation, Reports
Gt. Brit., MOS CDEE P. Transl. Great Britain, Ministry of Supply, Chemical Defense Experimental Establishment, Porton Translations
Gt. Brit., MOS GDC TIB Rep. & Transl. Great Britain, Ministry of Supply, Government Defense Council, Technical Information Bureau, Reports and Translations
Gt. Brit., MOS TIB S&T Memo. Great Britain, Ministry of Supply, Technical Information Bureau, Scientific and Technical Memorandum
Gt. Brit., NGTE Rep. Great Britain, National Gas Turbine Establishment, Reports
Gt. Brit., NPL Aerodynamics Div. Rep. Great Britain, National Physical Laboratory, Aerodynamics Division, Reports
Gt. Brit. RAE FPRC Rep. Great Britain, Royal Aircraft Establishment, Flying Personnel Research Committee, Reports
Gt. Brit., RAE Rep. Great Britain, Royal Aircraft Establishment, Reports
Gt. Brit., RAE RPD Rep. Great Britain, Royal Aircraft Establishment, Rocket Propulsion Department, Reports
Gt. Brit., RAE TN Aero.; TN Struc. Great Britain, Royal Aircraft Establishment, Technical Notes (Aeronautical; Structures)
Grumman Aircraft Eng. Corp. Res. Dept. Rep. Grumman Aircraft Engineering Corporation, Research Department, Reports

Handley-Page Bul. Handley-Page Bulletin
Harvard U. BHMO MR Studies; Rep. Harvard University, Blue Hill Meteor-

(*Continued on page 107*)

ological Observatory, Meteorological Radar Studies; Reports
Harvard U. Cruft Lab. TR. Harvard University, Cruft Laboratory, Technical Reports
Hawker Siddeley Rev. Hawker Siddeley Review
Hewlett-Packard J. Hewlett-Packard Journal
Hiller Helicopters, Papers
La Houille Blanche (France)
Hunting Group Rev. Hunting Group Review
Hydraulic Engr. Hydraulic Engineer
Hydraulisches Inst. Tech. Hochschule, München, Mitteil. Hydraulisches Institut der Technischen Hochschule von München, Mitteilungen

IAS Preprints; Papers. Institute of the Aeronautical Sciences, Preprints; Papers
IATA Bul. International Air Transport Association Bulletin
ICAO Bul. International Civil Aviation Organization Bulletin
IME Auto. Div. Proc. Institution of Mechanical Engineers, Automobile Division, Proceedings
IME Proc. (A). Institution of Mechanical Engineers, Proceedings (A)
IME Proc. (B), Appl. Mech.; Hydraulics. Institution of Mechanical Engineers; Proceedings (B), Applied Mechanics; Hydraulics
INCO. (International Nickel Company, Inc.)
Ind. & Eng. Chem. Industrial and Engineering Chemistry
Ind.-Anzeiger. Industrie-Anzeiger (Essen, Germany)
Ind. Labs. Industrial Laboratories
Ind. Quality Control. Industrial Quality Control
Ind. Sci. & Eng. Industrial Science and Engineering (Advanced-student edition of *Industrial Laboratories*)
Indian AF Quart. Indian Air Force Quarterly
Indian Airman
Indian Skyways
L'Ingegnere (Italy)
Ing.-Arch. Ingenieur-Archiv (Germany)
Inst. Français Transp. Aérien, Res. Papers. Institut Français du Transport Aérien, Research Papers
Inst. für Praktische Math. Tech. Hochschule. Institut für Praktische Mathematik, Technische Hochschule (Darmstadt, Germany)
Inst. Méc. Fluides, Lille. Institut de Mécanique des Fluides de Lille (France)
Inst. Sci. & Tech., Tokyo. Institute of Science and Technology (Japan)
Instrumentation
Instruments & Automation
Interavia (monthly)
Interchem. Rev. Interchemical Review
Internatl. Congr. Appl. Mech. Proc. International Congress for Applied Mechanics, Zurich, Proceedings
Internatl. Nickel Devel. & Res. Div. Tech. Bul. International Nickel Company, Development & Research Division, Technical Bulletins
Iowa Eng. Exp. Sta. Eng. Rep. Iowa Engineering Experiment Station, Iowa State College, Ames, Iowa, Engineering Report
IRE Trans., ANE; AP; CS; EC; MTT Ser. Institute of Radio Engineers, Transactions, Professional Groups on: Aeronautical and Navigational Electronics; Antennas and Propagation; Communications Systems; Electronic Computers; Microwave Theory and Techniques
Ireland, Meteorological Serv., Geophys. Pubs. Ireland, Meteorological Service, Geophysical Publications
Iron & Steel Engr. Iron and Steel Engineer
ISA J. Instrument Society of America, Journal
Istanbul Tech. U. Bul. Istanbul Technical University, Bulletin
Istanbul U. Fac. Sci. Rev., Ser. C. Istanbul University, Faculty of Sciences, Review (Fen Fakültesi Mecmuasi), Series C: Astronomy, Physics, and Chemistry

J. Acoustical Soc. Am. Journal of the Acoustical Society of America
J. ACS. Journal of the American Chemical Society
J. Aero. Sci. Journal of the Aeronautical Sciences
J. Aero. Soc. India. Journal of the Aeronautical Society of India
J. Air Law & Commerce. Journal of Air Law & Commerce
J. Appl. Mech. Journal of Applied Mechanics
J. Appl. Phys. Journal of Applied Physics
J. ARS. Journal of the American Rocket Society. See **Jet Propulsion**
J. ASNE. Journal of the American Society of Naval Engineers
J. Atmos. & Terrestrial Phys. Journal of Atmospheric & Terrestrial Physics
J. Av. Med. Journal of Aviation Medicine
J. Brit. Interplanetary Soc. Journal of the British Interplanetary Society
J. Electrodepositors' Tech. Soc. Journal of the Electrodepositors' Technical Society
J. Eng. Educ. Journal of Engineering Education
J. Franklin Inst. Journal of the Franklin Institute
J. GAPAN. Journal of the Guild of Air Pilots and Air Navigators
J. Helicopter Assn. Gt. Brit. Journal of the Helicopter Association of Great Britain
J. Hokkaidô Gakugei U., Sect. B. Journal of Hokkaidô Gakugei University, Section B (Japan)
J. Indian Inst. Sci. Journal of the Indian Institute of Science
J. Inst. Metals. Journal of the Institute of Metals
J. Inst. Navigation. Journal of the Institute of Navigation
J. Inst. Transp. Journal of the Institute of Transport
J. Japan Soc. Aero. Eng. Journal of the Japan Society of Aeronautical Engineering
J. Japan Soc. Appl. Mech. Journal of the Japan Society for Applied Mechanics
J. London Math. Soc. Journal of the London Mathematical Society
J. Math. & Phys. Journal of Mathematics and Physics
J. Mech. & Phys. Solids. Journal of the Mechanics and Physics of Solids
J. Meteorology. Journal of Meteorology
J. RAeS. Journal of the Royal Aeronautical Society
J. Sci. & Ind. Res. Journal of Scientific and Industrial Research
J. Sci. Instr. Journal of Scientific Instruments
J. Sci. Res. Journal for Scientific Research
J. SCMA. Journal of the Southern California Meter Association. In: **Instruments & Automation**
J. SLAE. Journal of the Society of Licensed Aircraft Engineers (incorporating *The Technical Instructor*)
J. So. African Interplanetary Soc. Journal of the South African Interplanetary Society
J. Southern Res. Journal of Southern Research
J. Space Flight. Journal of Space Flight
Japan, NCB Rep. Japan, Numerical Computation Bureau, Reports
Japan Sci. Rev. Japan Science Review (Engineering Sciences)
Japan Sci. Rev. Mech. & Elec. Eng. The Japan Science Review, Mechanical & Electrical Engineering
Jet Age
Jet Propulsion. (Formerly, **J. ARS**)

Konstruktion (Berlin)
Konstruktionbücher (Berlin)
Kunstoffe (Munich)
Kyushu U., Rep. Res. Inst. Appl. Mech. Kyushu University, Japan, Reports of Research Institute for Applied Mechanics

La. State U. Eng. Exp. Sta. Bul. Louisiana State University, Engineering Experiment Station, Bulletin
Lenkurt Demodulator
Lockheed Aircraft Rep. Lockheed Aircraft Corporation, Reports
Lockheed Field Serv. Dig. Lockheed Field Service Digest
The Log
Lubrication
Lubrication Eng. Lubrication Engineering

Mach. Des. Machine Design
Mag. of Magnesium. Magazine of Magnesium
Mag. of Standards. The Magazine of Standards
Magyar Kémiai Folyóirat (Budapest)
Marconi Rev. Marconi Review
Martin Star
Masch. und Wärmewirtschaft. Maschinenbau und Wärmewirtschaft (Austria)
Materials & Methods
Max-Planck-Inst. für Strömungsforschung, Mitteil. Max-Planck-Institut für Strömungsforschung, Mitteilungen (Göttingen)
Mec. Ind. (France)
Mech. Eng. Mechanical Engineering
Met. & Corrosion. Metaux et Corrosion (Paris)
Metal Prog. Metal Progress
Metal Treatment
Metall (Berlin)
Metallforschung (Berlin)
Metalloberfläche (Munich)
Metallurgia (Manchester, England)
Metallurgia Italiana (Milan)
Meteorological Mag. The Meteorological Magazine
Mil. Med. Military Medicine
Miss. State U. Eng. Res. Sta. Res. Rep. Mississippi State University, Engineering Research Station, Research Reports
MIT ASRL TR. Massachusetts Institute of Technology, Aeroelastic and Structures Research Laboratory, Technical Reports
Modern Metals
Motorola Newsgram
MTZ. Motor Technische Zeitschrift (Stuttgart)

N.C. State Coll. Eng. Sch. Bul. North Carolina State College, Engineering School Bulletin
Nachr. Öst. Betonver. Nachrichten Österreichischer Betonverein (Austria)
Natl. Acad. Sci. NRC Rep. National Academy of Sciences of the United States, National Research Council, Reports
Natl. Assn. State Av. Off. Papers. National Association of State Aviation Officials, Papers
NATO AGARD Memo. North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development, Memorandum
Naturwissenschaften (Berlin)

Nav. Res. Logistics Quart. Naval Research Logistics Quarterly
Naval Av. News. Naval Aviation News
Navigation
Netherlands, Koninklijke Nederlandse Akademie van Wetenschappen, Proc. (Proceedings)
Netherlands, Math. Centrum, Rep. Netherlands, Mathematisch Centrum (Amsterdam), Reports
Netherlands, NLL Rep. (Rep. & Trans.) Netherlands, Nationaal Luchtvaartlaboratorium (National Aeronautical Research Institute), Amsterdam, Reports (Reports and Transactions)
New Frontiers
New Zealand Flying
NFPA Bul.; Papers; Rep. National Fire Protection Association, Bulletins; Papers; Reports
NFPA Comm. Av. & Airport Fire Protection Bul.; Rep. National Fire Protection Association, Committee on Aviation and Airport Fire Protection, Bulletins; Reports
Noise Control
North Amer. Av. Spec. Res. Rep. North American Aviation Corporation, Special Research Reports
Northrop Rep. Northrop Aircraft, Inc., Reports
Notiz. Av. Notiziario di Aviazione (Rome)
NYU Col. Eng. Res. Rep.; Rev. New York University, College of Engineering, Research Reports; Reviews
NYU Res. Rev. New York University, College of Engineering, Research Review

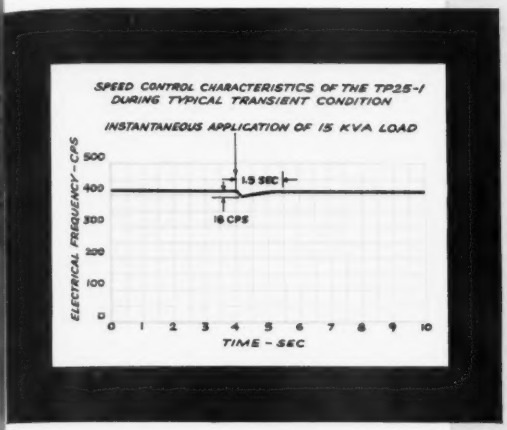
O. State U. Eng. Exp. Sta. News. The Ohio State University, Engineering Experiment Station, News
L'Onde Elec. L'Onde Electrique (Paris)
Ordnance
Ore. State Coll. Eng. Exp. Sta. Bul. Oregon State College, Engineering Experiment Station, Bulletin
Organic Finishing
The Oscillographer
Öst. Bauzeitschrift. Österreichische Bauzeitschrift (Vienna)

Pacific J. Math. Pacific Journal of Mathematics
Papers in Meteorology & Geophys. Papers in Meteorology and Geophysics
Pegasus
Penn. State U. Dept. Aero. Eng. TR. The Pennsylvania State University, Department of Aeronautical Engineering, Technical Reports
Philips Tech. Rev. Philips Technical Review
Philos. Mag. Philosophical Magazine
Philos. Trans. Royal Soc. (London), Ser. A. Philosophical Transactions of the Royal Society of London, Series A, Mathematical and Physical Sciences
Photogrammetria
Photogrammetric Eng. Photogrammetric Engineering
Photographic Eng. Photographic Engineering
Phys. Rev. The Physical Review
Polytech. Inst. Bklyn. Dept. Aero. Eng. & Appl. Mech. Polytechnic Institute of Brooklyn, Department of Aeronautical Engineering and Applied Mechanics
Power Jets Memo. Power Jets (Research and Development) Limited, Memorandum
Princeton U. Dept. Aero. Eng. Rep. Princeton University, Department of Aeronautical Engineering, Reports
Proc. Cambridge Philos. Soc. Proceedings, Cambridge Philosophical Society
Proc. IEE, Part I. Proceedings of the Institution of Electrical Engineers, Part I (General)
Proc. IEE, Part II. Proceedings of the Institution of Electrical Engineers, Part II (Power Engineering)
Proc. IEE, Part III. Proceedings of the Institution of Electrical Engineers, Part III (Radio and Communication Engineering)
Proc. Inst. Electronics. Proceedings of the Institution of Electronics (*Electronics Forum*)
Proc. IRE. Proceedings of the Institute of Radio Engineers
Proc. London Math. Soc., 2nd Ser.; 3rd Ser. Proceedings of the London Mathematical Society, 2nd Series; 3rd Series
Proc. Phys. Soc., Sect. B. Proceedings of the Physical Society (British), Section B
Proc. Royal Netherlands Acad. Sci., Amsterdam, Ser. A; Ser. B; Ser. C. Proceedings of the Royal Netherlands Academy of Sciences at Amsterdam, Series A (Mathematical Sciences); Series B (Physical Sciences, containing, e.g., Astronomy, Chemistry, Geology, Physics, Technical Sciences); Series C (Biological and Medical Sciences)
Proc. Royal Soc. (Edinburgh). Proceedings of the Royal Society (Edinburgh)
Proc. Royal Soc. (London), Ser. A. Proceedings of the Royal Society (London), Series A (Mathematical and Physical Sciences)
Prod. Eng. Product Engineering
Prof. Engr. Professional Engineer
Promotionsarb. Promotionsarbeiten, École Polytechnique Fédérale (Zurich)
Purdue U. TR. Purdue University, Technical Reports

Quadrangle
Quart. Appl. Math. Quarterly of Applied Mathematics
Quart. J. Mech. & Appl. Math. Quarterly Journal of Mechanics and Applied Mathematics
Quart. J. Royal Meteorological Soc. Quarterly Journal of the Royal Meteorological Society

Radio & TV News. Radio & Television News
Radio-Electronic Eng. Radio-Electronic Engineering Section (formerly a section in **Radio & TV News**)
Radio Tech. Comm. Aeronautics, Papers. Radio Technical Commission for Aeronautics, Papers
RAND Corp. Transl. The RAND Corporation, Translations
RCA Rev. RCA Review
La Recherche Aéronautique (Paris)
Rend. Accad. Naz. dei Lincei, Classe Sci. Fis. Mat. e Natl. Rendiconti dell'Accademia Nazionale dei Lincei, Classe de Scienze Fisiche, Matematiche e Naturali (Italy)
Rensselaer Polytech. Inst. Dept. Aero. Eng. TR. Rensselaer Polytechnic Institute, Department of Aeronautical Engineering, Technical Reports
Rep. Inst. Sci. & Tech. Report of the Institute of Science and Technology (Tokyo)
Republic Av. Rep. Republic Aviation Corporation, Reports
Res. Trends (Cornell Aero. Lab.). Research Trends (Cornell Aeronautical Laboratory, Inc.)
RETMA Electronic Appl. Reliability Rev. Radio-Electronics-Television Manufacturers Association, Electronic Applications Reliability Review
Rev. Aero. Revista de Aeronáutica (Madrid)
Rev. Nac. Aero. Revista Nacional de Aeronautica (Buenos Aires)
Rev. Sci. Instr. Review of Scientific Instruments (London)
Rev. Universelle des Mines. Revue Universelle des Mines (Liége, Belgium)
Reynolds Metals Tech. Adviser. Reynolds Metals Technical Adviser
Ricerca Sci. La Ricerca Scientifica (Rome)
Riv. Aero. Rivista Aeronautica (Rome)
Riv. Meteorologia Aero. Rivista di Meteorologia Aeronautica (Rome)
Rockets
Rolls-Royce Bul. Rolls-Royce Bulletin
Rozprawy Inżynierskie. Instytut Podstawowych Problemów Techniki, Polska Akademia Nauk (Warsaw)
Rumania, Acad. Rumanian People's Rep., Inst. Appl. Mech., Studies & Res. in Appl. Mech. Rumania, Academy of the Rumanian People's Republic, Institute of Applied Mechanics, Studies and Researches in Applied Mechanics (Studii si Cercetari de Mecanica Aplicata)
Ryan Reporter

Saab Sonics (Sweden)
Saab TN. Saab Technical Notes
SAE Aero. Info. Rep. Society of Automotive Engineers, Aeronautical Information Reports
SAE J. SAE Journal
SAE Preprints; Papers. Society of Automotive Engineers, Preprints; Papers
Sailplane & Glider
Saro Prog. Saro Progress
Schweissen und Schneiden (Düsseldorf)
Schweizer Arch. Schweizer Archiv (Solothurn, Switzerland)
Sci. Mo. The Scientific Monthly
Science
Sheet Metal Ind. Sheet Metal Industries (London)
Shell Av. News. Shell Aviation News
Siemens Z. Siemens Zeitschrift (Berlin)
Siemenstadt, Mitteil. Forsch. Lab. Siemenstadt, Mitteilung und Forschung Laboratorium (Germany)
Skyline (North American Aviation, Inc.)
Skyways
SNCASO Papers. Société Nationale de Constructions Aéronautiques du Sud-Ouest, Papers
Soaring
Solar Blast
SPE J. Society of Plastics Engineers, Journal
Sperry Eng. Rev. Sperry Engineering Review
Sperry Gyroscope Rep. Sperry Gyroscope Company, Reports
Sperry Rev. Sperry Review
Sperryscope
Stahl und Eisen (Düsseldorf)
Stanford Res. Inst. Res. Ind. Stanford Research Institute, Research for Industry
Stanki i Instr. Stanki i Instrumenti (Moscow)
State Coll. Ia. Eng. Sta. TR. State College of Iowa, Engineering Experiment Station, Technical Reports
Steel Horizons
Steel Processing
Stockholm, KTH AERO TN. Stockholm, Kungliga Tekniska Högskolan, Institutionen för Flygteknik, Technical Notes
Stockholm, KTH IBS Medd. Stockholm, Kungliga Tekniska Högskolan, Institutionen för Byggnadsstatik, Meddelanden
Structural Engr. Assn. Calif. Rep. Structural Engineers Association of California, Reports
Stuttgart Tech. Hochsch. Stuttgart Technische Hochschule (Germany)
Sverdrup & Parcel Transl. Rep. Sverdrup & Parcel, Inc., Translation Reports



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Sweden, Flygtekniska Försöksanstalten, FFA Medd. (The Aeronautical Research Institute of Sweden, Reports)
Syracuse U. Transp. Conf. Papers. Syracuse University, Transportation Conference, Papers

Taylor Tech. Taylor Technology
Tech. et Sci. Aéronautiques. Technique et Science Aéronautiques (Paris)
Tech. Rev. Technology Review
Tek. Lotnicza. Teknika Lotnicza (Poland)
Teknisk Ukeblad (Oslo)
Tele-Tech
Tôhoku U. Rep. Inst. High Speed Mech. Tôhoku University (Sendai, Japan), The Reports of the Institute of High Speed Mechanics. The Science Reports of the Research Institutes, Series B (Technology)
Tool Engr. Tool Engineer
Trans. AIEE. Transactions of the American Institute of Electrical Engineers
Trans. ASME. Transactions of the American Society of Mechanical Engineers
Trans. Inst. Welding. Transactions of the Institute of Welding
Trans. SNAME. Transactions of the Society of Naval Architects and Marine Engineers
Trans. Soc. Inst. Tech. Transactions of the Society of Instrument Technology
Transp. & Commun. Rev. Transport and Communications Review
Trend in Eng. The Trend in Engineering

U. Ark. Engr. Exp. Sta. Bul. University of Arkansas, Engineering Experiment Station, Bulletin
U. Calif. Pubs. in Eng. University of California, Publications in Engineering
U. Ill. Bul. University of Illinois, Bulletins
U. Ill. Eng. Exp. Sta. Bul.; TR. University of Illinois, Engineering Experiment Station, Bulletins; Technical Reports
U. Md. Inst. Fluid Dynamics & Appl. Math., Lecture Ser. University of Maryland, Institute for Fluid Dynamics and Applied Mathematics, Lecture Series
U. Mich. Eng. Res. Inst. Rep. University of Michigan, Engineering Research Institute, Reports
U. Mich. Icing Res. Cen. Rep.; Transl. University of Michigan, Icing Research Center, Reports; Translations
U. Minn. Inst. Tech. Dept. Aero. Eng., Res. Rep. University of Minnesota, Institute of Technology, Department of Aeronautical Engineering, Research Reports
U. Nac. Eva Peron, Fac. Ciencias Fisicomat., Pubs. Universidad Nacional Eva Peron, Publicaciones de la Facultad de Ciencias Fisicomatematicas
U. Toronto Inst. Aerophys. Rev.; Rep. University of Toronto, Institute of Aerophysics, Review; Reports
U. Wash. Eng. Exp. Sta. Bul.; Reprints. University of Washington, Engineering Experiment Station, Bulletins; Reprints
U. Wis. NRL Dept. Chem. Rep. University of Wisconsin, Naval Research Laboratory, Department of Chemistry, Reports
United Air Lines News
U.S., Bur. Mines Bul.; Rep. Invest. United States, Bureau of Mines, Bulletin; Report of Investigations
U.S., CAA AEE Rep. United States, Civil Aeronautics Administration, Airframe and Equipment Engineering Reports
U.S., CAA AOD Papers; Rep. United States, Civil Aeronautics Administration, Airways Operations Division, Papers; Reports
U.S., CAA TDR. United States, Civil Aeronautics Administration, Technical Development Reports
U.S., Dept. Comm., Bus. & Defense Serv. Admin., Pamphlets; Rep. United States, Department of Commerce, Business and Defense Services Administration, Pamphlets; Reports
U.S., Forest Prod. Lab. Rep. United States, Forest Products Laboratory, Madison, Wis., Reports
U.S., NACA Rep.; RM; TM; TN. United States, National Advisory Committee for Aeronautics, Report; Research Memorandum; Technical Memorandum; Technical Notes
U.S., NADC Rep. United States, Naval Air Development Center, Reports
U.S., NAES Rep. United States, Naval Air Experiment Station, Reports
U.S., Nav. Sch. Av. Med., Pensacola, Fla., Project Rep. United States, Naval School of Aviation Medicine, Naval Air Station, Florida, Project Reports
U.S., NavBuAer RDR. United States, Navy Department, Bureau of Aeronautics, Research Division Reports
U.S., NAVORD Rep. United States, Naval Ordnance Reports
U.S., Navy Dept., David W. Taylor Model Basin, Rep.; Transl. United States, Navy Department, David W. Taylor Model Basin, Reports; Translations
U.S., NBS Appl. Math. Ser. United States, National Bureau of Standards, Applied Mathematics Series
U.S., NBS J. Res. United States, National Bureau of Standards, Journal of Research
U.S., NBS Rep. United States, National Bureau of Standards, Reports
U.S., NBS Sum. TR. United States, National Bureau of Standards, Summary Technical Reports
U.S., NBS Tech. News Bul. United States, National Bureau of Standards, Technical News Bulletin
U.S., NRL Rep. United States, Naval Research Laboratory, Reports
U.S., ONR Res. Rep. United States, Office of Naval Research, Research Report (monthly)
U.S., ONR Special Devices Cen. TR. United States, Office of Naval Research, Special Devices Center, Technical Reports
U.S., Weather Bur. Mo. Weather Rev. United States, Weather Bureau, Monthly Weather Review
U.S. AEC Rep. United States Atomic Energy Commission, Reports
U.S. Air Serv. U.S. Air Services
U.S. Armed Forces Med. J. United States Armed Forces Medical Journal
U.S. Naval Inst. Proc. United States Naval Institute, Proceedings
U.S. Steel Lubricants Testing Lab. Rep. United States Steel Lubricants Testing Laboratory, Reports
USAF AMC Eng. Div. Aero. Med. Lab. TR. United States Air Force, Air Materiel Command, Engineering Division, Aero Medical Laboratory, Technical Reports
USAF APG Rep. United States Air Force, Air Proving Ground, Reports
USAF Arctic Aeromed. Lab. Project Rep. United States Air Force, Arctic Aeromedical Laboratory, Alaska, Project Reports
USAF FTC TR. United States Air Force, Flight Test Center, Technical Reports
USAF MATS Rep.; Papers. United States Air Force, Military Air Transport Service, Reports; Papers
USAF OSR TN. United States Air Force, Office of Scientific Research, Air Research and Development Command, Technical Notes
USAF RADC TR. United States Air Force, Rome Air Development Center, Technical Reports
USAF SAM Rep. United States Air Force, School of Aviation Medicine, Reports
USAF TR. United States Air Force, Technical Reports
USCEC Rep.; TN. University of Southern California, Engineering Center, Reports; Technical Notes

Va. J. Sci. The Virginia Journal of Science
VDE Fachber. Verein Deutscher Elektrotechniker, Fachberichte (Germany)
VDI-Forschungsheft. Verein Deutscher Ingenieure, Verlag, Forschungsheft (Düsseldorf)
Vitesse-Speed (Paris)
VPI Eng. Exp. Sta. Ser. Bul. Virginia Polytechnic Institute, Engineering Experiment Station, Series Bulletin
VTH. Vliegtuigbouwkunde Technische Hogeschool (Delft)

W. U. Tech. Rev. Western Union Technical Review
Welding J. Welding Journal
Welding J. Res. Suppl. Welding Journal, Research Supplement
Welding Res. Welding Research (London)
Weltraumfahrt (Frankfurt am Main)
Western Av. Western Aviation
Westinghouse Engr. Westinghouse Engineer
Whites' Av. Whites' Aviation
Wireless Engr. Wireless Engineer
Wireless World
WMO Bul. World Meteorological Organization Bulletin

Young Men (Air Trails)

Z. für Elektrochemie. Zeitschrift für Elektrochemie (Halle, Germany)
Z. für Instrumentkunde. Zeitschrift für Instrumentkunde (Berlin)
Z. für Metallkunde. Zeitschrift für Metallkunde (Berlin)
Z. für Naturf. Zeitschrift für Naturforschung (Wiesbaden, Germany)
Z. VDI. Zeitschrift des Vereins Deutscher Ingenieure (Berlin)
ZAMM. Zeitschrift für angewandte Mathematik und Mechanik (Berlin)
ZAMP. Zeitschrift für angewandte Mathematik und Physik (Zurich)
ZAP. Zeitschrift für angewandte Physik (Berlin)
ZFW. Zeitschrift für Flugwissenschaften (Braunschweig)
Zhur. Tekh. Fiz. Zhurnal Tekhnischeskoi Fiziki (Moscow)
Zurich Tech. U. Papers. Zurich Technological University, Papers
ZWB UM. Zentrale für Wissenschaftliches Berichtswesen über Luftfahrtforschung, Untersuchungen und Mitteilungen (Munich)

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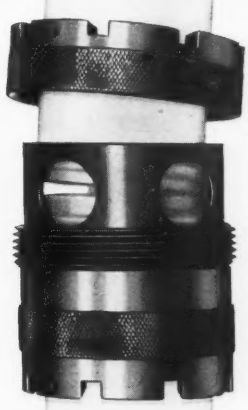
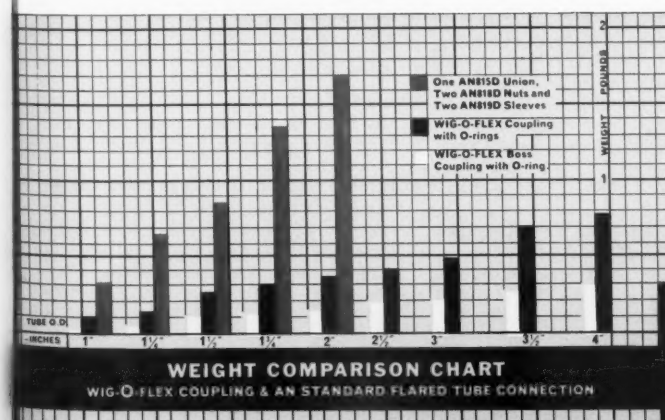


flexible union for connecting rigid tubes



WEIGHT COMPARISON CHART
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- Installs locally. 80% lighter.
- Temperature range —65°F to +250°F.

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Acoustics, Sound, and Noise

Effect of Exhaust-Nozzle Ejectors on Turbojet Noise Generation. Warren J. North and Willard D. Coles. *U.S., NACA TN 3573*, Oct., 1955. 26 pp.

Geometrical Theory of Sound Propagation in the Atmosphere. G. V. Groves. *J. Atmospheric & Terrestrial Phys.*, Sept., 1955, pp. 113–127. 14 refs.

The Influence of Propeller Synchrophasing on Aircraft Cabin Noise. G. E. Sanderson. *SAE Golden Anniv. Aero. Meeting, Los Angeles, Oct. 11–15, 1955, Preprint 595.* 4 pp.

The Non-Existence of Steady Acoustic Lag in Airborne Pressure Measuring Systems. B. G. Newman. *Canada, NAE LR-100A*, July, 1955. 8 pp. A corrigendum to *NAE LR-100*, Apr., 1954.

A Propeller Synchrophaser for Aircraft Noise Control. Charles B. Brahm. *SAE Golden Anniv. Aero. Meeting, Los Angeles, Oct. 11–15, 1955, Preprint 594.* 7 pp. Results of Hamilton Standard investigations, with a description of the design and operational features of the electromechanical Hydromatic Synchrophaser system used on the Lockheed 1649 Super-Constellation.

Sound Propagation Into the Shadow Zone in a Temperature-Stratified Atmosphere Above a Plane Boundary. Appendix A—Approximation of a Slowly Varying Medium. Appendix B—Approximation to Wave Equation. Appendix C—Simplification of Eigenvalue Equation. Appendix D—Temperature Distribution in a Rectangular Enclosure. David C. Pridmore-Brown and Uno Ingard. *U.S., NACA TN 3494*, Oct., 1955. 57 pp. 11 refs.

Study of Screeching Combustion in a 6-Inch Simulated Afterburner. Appendix A. Appendix B—Distortion and Diminution of Sound Waves of Finite Amplitude in Tubes. Perry L. Blackshear, Warren D. Rayle, and Leonard K. Tower. *U.S., NACA TN 3567*, Oct., 1955. 58 pp. 14 refs. Theoretical development for the case of nonlinear attenuation of high-amplitude sound in tubes.

Aerodynamics

Boundary Layer

Boundary-Layer Characteristics for Smooth and Rough Surfaces. Francis R. Hama. *Trans. SNAME*, 1954, pp. 333–351; Discussion, pp. 351–358. 41 refs. Reprint. Wind-tunnel measurements of the velocity distribution along a plate covered by a series of artificial roughnesses of controlled characteristics.

The Critical Study of a Boundary Condition on Prandtl's Boundary Layer Theory and Its Applications. Sin-I Cheng. *Princeton U. Dept. Aero. Eng. Rep. 329*, Sept., 1955. 36 pp. USAF-supported theoretical and experimental investigation of viscous effects in supersonic flows.

Effects of Boundary-Layer Control System Efficiency on Performance. Robert K. Wattson, Jr. *Aero. Eng. Rev.*, Dec., 1955, pp. 49–51. Theoretical evaluation based on the energy concept of independent and integrated systems in terms of take-off acceleration, climb, and range potentialities.

The Downstream Effect of a Local Thickening of the Laminar Boundary Layer. D. G. Hurley. *Australia, ARL AN 146*, July, 1955. 7 pp.

On the Growth of Taylor-Görtler Vortices Along Highly Concave Walls. A. M. O. Smith. (*Douglas Rep. ES 17110*, Mar. 3, 1953.) *Quart. Appl. Math.*, Oct., 1955, pp. 233–262. 14 refs. Abridged. Solution of the eigenvalue problem using a laminar-boundary-layer stability chart based on the Galerkin variational method.

Some Aspects of Unsteady Laminar Boundary Layer Flows. Sin-I Cheng. *Princeton U. Dept. Aero. Eng. Rep. 311*, July 1, 1955. 64 pp. USAF-supported theoretical and experimental analysis of viscous effects in supersonic flow.

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An Experimental Introduction to the Jet Flap. N. A. Dimmock. *Gt. Brit., NGTE Rep. R.175*, July, 1955. 68 pp. Tests on two-dimensional airfoils of a 12.5 per cent thick elliptical cross section with a narrow full span jet slot at the trailing edge, with the jet deflections at 90° and 31.4°.

Jet Flap. I. I. M. Davidson. (*RAeS Paper*, Oct. 20, 1955.) *The Engr.*, Oct. 28, 1955, pp. 617–619. (Also in *The Aeroplane*, Oct. 28, 1955, pp. 672–674.) 12 refs. Abridged. Review of powered-lift investigations on the large Fowler-flap-like behavior of jet-flapped airfoils based on an aerodynamic resynthesis of the lifting and propulsive means, taking into account the supercirculation phenomena.

Measurements of Two-Dimensional Derivatives on a Wing-Aileron-Tab System with a 1541 Section Aerofoil. I—Direct Aileron Derivatives. K. C. Wight. *Gt. Brit., ARC R&M 2934* (Oct., 1952), 1955. 18 pp. BIS, New York. $1.25.

Pressure Distributions Illustrating Flow Reattachment Behind a Forward Mounted Flap. E. C. Maskell. *Gt. Brit., ARC CP 211* (Mar., 1954), 1955. 22 pp. BIS, New York. $0.75. Tests on an NACA.0015 wing to study the physical nature of the flow behind the flap.

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The Motion of a Viscous Fluid Conducting Heat. J. L. Synge. *Quart. Appl. Math.*, Oct., 1955, pp. 271–278. 10 refs. Derivation of simple equations governing the behavior of the fluid using specific entropy and specific volume as basic thermodynamic variables.

On a Method of Generating Three-Dimensional Potential Flows from Two-Dimensional Ones. Chia-Shun Yih. *Quart. Appl. Math.*, Oct., 1955, pp. 320–322.

Perturbation Theory of Wave Propagation Based on the Method of Characteristics. Phyllis A. Fox. *J. Math. & Phys.*, Oct., 1955, pp. 133–151. 12 refs. Expansion-procedural analysis of the shock-wave development as applied to the cases of motion due to an initial periodic density distribution and to the periodic oscillation of a piston.

Some Effects of the Addition of Heat to a One-Dimensional High Speed Air Flow. P. S. Barna. *Australia, ARL Rep. ME. 13*, Nov., 1954. 53 pp.

The Theories of Turbulence. L. Agostini and J. Bass. (*France, Min. de l'Air PST 237*, 1950.) *U.S., NACA TM 1377*, Oct., 1955. 163 pp. 43 refs. Translation. Includes detailed analyses of such aspects as the kinematics of statistical mediums and velocity correlations, the application of the Navier equations to turbulent motion, and physical theories involving similarity hypotheses.

Aerodynamic Derivatives for Both Steady and Nonsteady Motion of Slender Bodies. R. M. Wood and C. H. Murphy. *J. Aero. Sci.*, Dec., 1955, pp. 870, 871.

Application de la Théorie des Mouvements Homogènes au Calcul de la Traînée d'Onde d'Ailes en Flèche Effilées. M. Fenain and D. Vallée. *La Recherche Aéronautique*, Mar.–Apr., 1955, pp. 9–21. In French. Application of the Germain theory of homogeneous movements to the calculation of the wake of sweptback wings, with an analysis of the effect of the parameters of span and position of maximum profile thickness determining the profile evolution on the wake.

The Characteristic Frequencies of Small Oscillations in the Flow Past Bluff Bodies. D. A. Spence. *Gt. Brit., RAE Rep. Aero. 2532*, May, 1955. 23 pp. 16 refs.

Leading Edge Effects on the Flow Over a Flat Plate at Hypersonic Speeds. A. G. Hammitt, I. E. Vas, and S. M. Bogdonoff. *Princeton U. Dept. Aero. Eng. Rep. 326*, Sept., 1955. 31 pp. 16 refs. USAF-supported investigation including optical studies over a range of leading-edge thicknesses covering a ratio of 350 to 1 and pressure distribution data for the thicker end of the range.

On Source and Vortex of Fluctuating Strength Travelling Beneath a Free Surface. H. S. Tan. *Quart. Appl. Math.*, Oct., 1955, pp. 314–317.

Supersonic Flow Past Slender Bodies of Elliptic Cross-Section. Appendix—The Effect of Discontinuities in the Source and Multi-Source Strength and Their Derivatives. L. E. Fraenkel. *Gt. Brit., ARC R&M 2954* (May, 1952), 1955. 27 pp. BIS, New York. $1.70.

Sur l'Écoulement Subsonique au Voisinage de la Pointe Avant d'une Aile Delta. P. Germain. *La Recherche Aéronautique*, Mar.–Apr., 1955, pp. 3–8. In French. Study of the subsonic flow in the vicinity of the apex of a delta wing to prove its homogeneous characteristics.

Internal Flow

Effect of Variable Viscosity and Thermal Conductivity on High-Speed Slip Flow Between Concentric Cylinders. Appendix A. Appendix B—Transformation of Equations of Motion to Polar Coordinates. Appendix C—Reduction of Boundary Conditions to Dimensionless Form. Appendix D—Determination of Approximate Expressions for Distributions. T. C. Lin and R. E. Street. (*U.S., NACA TN 2895*, 1953.) *U.S., NACA Rep. 1175*, 1954. 36 pp. 23 refs. Supt. of Doc., Wash. $0.35.

Application of the Lighthill Mathematical Method to the Test Cascade Design. A. W. Wright and E. Szomanski. *Aus-*

(*Continued on page 128*)

INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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Volume 1, Number 1 January, 1956

ACOUSTICS, SOUND, AND NOISE

A THEORETICAL ANALYSIS OF THE FIELD OF A RANDOM NOISE SOURCE ABOVE AN INFINITE PLANE. Peter A. Franken. U.S., NACA TN 3557, Nov., 1955. 20 pp. Use of a finite-band-width receiver for atmospheric acoustic measurements in the far field for the special case of a perfectly reflecting plane, with an extension to include the case of a plane of arbitrary impedance.

AERODYNAMICS

GENERAL SOLUTIONS OF OPTIMUM PROBLEMS IN NONSTATIONARY FLIGHT. Appendix ---PROBLEMS OF ABSOLUTE OPTIMUM. Angelo Miele. (L'Aerotecnica, Rome, No. 3, 1952, pp. 135--142.) U.S., NACA TM 1388, Oct., 1955. 25 pp. Translation. Development of flight techniques for such conditions as climb with minimum time and fuel consumption, steepest climb, and descending and gliding with maximum time or distance, with a derivation of optimum distributions of speed with altitude assuming constant airplane weight and neglecting curvatures and squares of path inclination in the projection of the equation of motion on the normal to the flight path; includes critical analysis of the physical nature of the relative merits of the solutions for practical applications.

Boundary Layer and Thermoaerodynamics

BOUNDARY-LAYER MEASUREMENTS IN HYPERSONIC FLOW. F. K. Hill. J. Aero. Sci., Jan., 1956, pp. 35--42. 19 refs. NAVORD-supported experimental calculations at Johns Hopkins U. of the boundary-layer formation, heat transfer, and skin-friction coefficient at Mach Numbers of 8.25 and 9.0 on the wall of a conical nozzle in the presence of a favorable pressure gradient and several rates of heat transfer, with Reynolds Numbers based on momentum thickness varied between 1,500 and 3,500, and with a comparison to flow data at lower Mach Numbers and to those of the von Karman semiempirical theory.

CALCULATIONS FOR MASS TRANSFER AT A PLANE SURFACE ALONG WHICH FLOW OCCURS, AT HIGH PARTIAL PRESSURE GRADIENTS (BERECHNUNG DES STOFFÜBERGANGES AN EINER EBENEN, LÄNGSANGESTRÖMTEN OBERFLÄCHE BEI GROSSEM TEILDRUCKGEFALLE). E. Eckert and V. Lieblein. (Forschung Gebiete Ing., Berlin, Mitteil., No. 2, 1949, pp. 33--42.) Gt. Brit., RAE Lib. Transl. 540, Sept., 1955. 19 pp. 10 refs. Analysis for the formation of a laminar boundary layer under the assumption that constant temperature prevails inside the boundary layer and that the molecular weights of diffusing substance and carrier gas are practically the same, with numerical results for the diffusion of water vapor into air.

THE DEVELOPMENT OF TURBULENT BOUNDARY LAYERS. D. A. Spence. J. Aero. Sci., Jan., 1956, pp. 3--15. 21 refs. Investigation based on Schubauer-Klebanoff, Ludwieg-Tillmann, and Townsend experiments and using the power law $u/U = (y/\delta)^n$ related to equations of momentum, skin friction, and form parameters and to the velocity profiles and the eddy structure of the boundary layer; includes: a simple numerical step-by-step integration method for the development of equations without the required use of velocity derivatives to permit a rapid examination of the effect of variations in the initial conditions, taking into account the effect of the increase in the initial thickness on separation and a possible increase of Reynolds Numbers to delay the separation, in opposition to the von Doenhoff-Tetervin theory; and a derived approximation equation in functional form for the variation of the form parameter in an adverse pressure gradient to predict boundary-layer growths.

AN ANALYSIS OF AERODYNAMIC DATA ON BLOWING OVER TRAILING EDGE FLAPS FOR INCREASING LIFT. Appendix I. Appendix II--- BLOWING COEFFICIENTS FOR COMPRESSIBLE SLOT FLOWS. J. Williams. Gt. Brit., ARC CP 209 (Sept., 1954), 1955. 33 pp. 25 refs. BIS, New York. $ 0.90. Evaluation of wind-tunnel boundary-layer-control test results, with tentative

proposals of simple methods for the practical prediction of the lift increment at constant incidence attainable on finite wings and the associated increase in pitching moment, and with theoretical curves related to compressible isentropic flow through the blowing slot for the determination of the various blowing coefficients in terms of the blowing pressure ratio.

EFFECTS OF BOUNDARY-LAYER CONTROL SYSTEM EFFICIENCY ON PERFORMANCE. R. K. Wattson, Jr. Aero. Eng. Rev., Dec., 1955, pp. 49--51. Theoretical evaluation based on the energy concept of independent and integrated systems in terms of lift and drag effects, take-off acceleration, climb, and range potentialities, with the analysis based on the fundamental equation

$$-\frac{WV}{g}\frac{dV}{dt} - W\frac{dh}{dt} + \eta H\frac{dW_f}{dt} - DV = 0$$

and with a modification for the useful propulsion power in a BLC integrated system expressed as an "engine efficiency" factor representing the conversion of fuel energy to shaft power.

A SIMPLE APPROXIMATE METHOD FOR CALCULATING THE LAMINAR BOUNDARY LAYER WITH SUCTION. E. Truckenbrodt. Braunschweig Tech. Hochschule Inst. Strömungsmech., Rep. 55/6a, May 21, 1955. 62 pp. 13 refs. USAF-sponsored development of the method applied to cases of two-dimensional and axially symmetrical flows with an arbitrary distribution of suction velocity along the surface, and with comparisons to solutions from other approximations.

TURBULENT BOUNDARY LAYER CONTROL BY RAMPS OR WEDGES. A. V. Stephens and G. A. Collins. Australia, Aero. Res. Comm. Rep. ACA-55, May, 1955. 19 pp. Experimental development of means of delaying or eliminating turbulent separation through redistribution of total pressure in a boundary layer using wedge-shaped excrescences on the surface, with wind-tunnel supporting data.

CONTROL SURFACES

MEASUREMENTS OF TWO-DIMENSIONAL DERIVATIVES ON A WING-AILERON-TAB SYSTEM WITH A 1541 SECTION AEROFOIL. I---DIRECT AILERON DERIVATIVES. K. C. Wight. Gt. Brit., ARC R&M 2934 (Oct., 1952), 1955. 18 pp. BIS, New York. $1.25. 9 x 7 ft. low-speed wind-tunnel calculations in incompressible flow of damping and stiffness derivatives for a 20 per cent aileron to analyze the effects of frequency parameter, Reynolds Number, amplitude of oscillation, position of transition on the wing, and mean aileron angle.

THEORETICAL AND EXPERIMENTAL INVESTIGATIONS ON DELTA-WINGS WITH FLAPS. E. Truckenbrodt and K. H. Gronau. Brauhschweig Tech. Hochschule Inst. Strömungsmech. Rep. 55/12a, June 22, 1955. 45 pp. USAF-sponsored calculations based on the Truckenbrodt lifting-surface theory on five plan forms of 0.8--3.9 aspect ratios to determine characteristics of various flap arrangements and deflections in incompressible flow, with supporting wind-tunnel measurements.

Fluid Mechanics & Aerodynamic Theory

ANALYTICAL TREATMENT OF TWO-DIMENSIONAL SUPERSONIC FLOW. I---SHOCK FREE FLOW. R. E. Meyer and J. J. Mahony. II---FLOW WITH WEAK SHOCKS. J. J. Mahony. Australia, ARL Rep. A.93, A.94, Apr., 1955. 64, 33 pp. 29 refs. Approximate solution for the general wave-interaction problem of steady irrotational, homentopic flow of a perfect gas, with a calculation using Riemann functions of the pressure distribution in the first interaction region of a jet expanding from a perfect nozzle, and with an extension of the Friedrichs method neglecting any entropy variations produced by weak shocks as used for the illustrative cases of a thin airfoil in a nonuniform stream, a shock starting from the cusp of a limit line, and a first shock in an expanding supersonic jet; includes provisions for error estimation.

INTERACTION OF A SHOCK WAVE WITH A THERMAL BOUNDARY LAYER. W. C. Griffith. J. Aero. Sci., Jan., 1956, pp. 16--22, 66. Investigation using an experimental technique of sliding a hot plate into the shock tube before the shock occurs to develop a linearized theory based on the Lighthill method of obtaining the shock shape and flow field for cases of a shock sufficiently strong and the heating small enough for the shock to extend clear to the surface, with a determination of the time required for the establishment of steady conditions, and with results of tests on the validity of the theoretical basis using shocks up to a pressure ratio of 1.36 and surface temperatures up to 80°C.

DÉTERMINATION D'UN ÉCOULEMENT COMPRESSIBLE SUBSONIQUE À PARTIR D'UN ÉCOULEMENT INCOMPRESSIBLE. P. Bevière. La Recherche Aéronautique, July-Aug., 1955, pp. 3--5. In French. Application of an approximation law of compressibility to the determination of subsonic flows about a profile from incompressible flow characteristics using methods based on transformations of a flow function and of the speed potential.

ON VARIATIONAL PRINCIPLES FOR REAL FLUIDS. Paul Lieber, Olaf Anderson, and K. S. Wan. Rensselaer Polytech. Inst. Dept. Geol. OSR TN 55-370, Oct., 1955. 35 pp. Theoretical development of a lifting theory for bodies of revolution not governed by the Kutta theory to provide a mathematical formulation for the Minimum Dissipation Condition related to the associated Euler equations and based on the Calculus of Variation applied to the determination as a special solution of the biharmonic equation of drag of a circular cylinder produced by a potential viscous flow and a formulation for the virtual displacement of a real fluid in terms of the Euler general hydrodynamic momentum equations; applications of the minimum principle include problems of real flow between parallel plates and of the boundary-layer theory.

THE THEORIES OF TURBULENCE. L. Agostini and J. Bass. (France, Min. de l'Air PST 237, 1950.) U.S., NACA TM 1377, Oct., 1955. 163 pp. 43 refs. Translation. Summary of conference proceedings at the Paris Inst. of Mech., Sorbonne, covering theoretical and experimental findings; includes detailed analyses of such aspects as the kinematics of statistical mediums and velocity correlations, the application of the Navier equations to turbulent motion, physical theories involving similarity hypotheses, measuring techniques and instrumentation, statistical methods, and research trends; with experimental time-correlation and spectrum curves determined by Favre at the Marseille Inst. of Fluid Mech.

Internal Flow

APPLICATION NUMÉRIQUE D'UN CALCUL D'AMORTISSEMENT AÉRODYNAMIQUE DES VIBRATIONS D'AUBES DE COMPRESSEURS. E.-A. Eichelbrenner. La Recherche Aéronautique, July-Aug., 1955, pp. 7--14. In French. Estimate of aerodynamic damping of compressor blade vibrations for the case of a blade grid inclined at 45°, with a determination of the damping curves as related to the reduced frequency and form of the vibrations and as compared to those corresponding to an isolated blade indicating the influence of cascade design on the general characteristics of the curves.

CALCUL D'UNE GRILLE D'AUBES POUR UNE DISTRIBUTION DE NOMBRES DE MACH SUBSONIQUES DONNÉE EN FONCTION DU POTENTIEL. Robert Legendre. La Recherche Aéronautique, Sept.-Oct., 1955, pp. 3--9. In French. Calculation of a blade grid for a distribution of subsonic Mach Numbers given as a function of the potential, with two successive integrations for the velocity and flow area, particularly developing the profile form.

COMPRESSIBILITY EFFECTS ON SECONDARY FLOWS. H. G. Loos. J. Aero. Sci., Jan., 1956, pp. 76--80. USAF-sponsored investigation at the CIT Jet Propulsion Center generalizing the Hawthorne computational method for problems of the secondary vorticity applied to cascades approached by a flow with a boundary layer developed along an insulated wall and with a Prandtl Number equal to unity, with an analysis of the influence of compressibility caused by the entropy gradient in the approaching flow and the compression of the fluid during the turning of the flow.

A SURVEY OF UNCLASSIFIED AXIAL-FLOW-COMPRESSOR LITERATURE. Howard Z. Herzig and Arthur G. Hansen. U.S., NACA RM E55H11, Nov. 8, 1955. 88 pp. 253 refs. Review of theoretical and experimental flow and design studies of: airfoils, cascades, stationary and rotating blade rows, stators, and rotors; single-stage and multistage compressor performance, characteristics, parameters, velocity diagrams, boundary-layer effects, testing techniques, and instrumentation; effects of streamline curvature and radial variation of circulation, time-unsteady and viscous flows, three-dimensional and secondary flows, compressibility, Mach Number, and end losses.

AN EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER AT THE BOUNDARIES OF SUPERSONIC NOZZLES. Appendix I---HEAT TRANSFER AND SKIN FRICTION IN THE PRESENCE OF A CONSTANT PRESSURE GRADIENT FOR A TURBULENT BOUNDARY LAYER. Appendix II---CORRECTION FOR ARBITRARY SURFACE-TEMPERATURE DISTRIBUTION. J. R. Baron and F. H. Durgin. USAF WADC TR 54-541, Dec., 1954. 75 pp. 27 refs. Studies at the MIT Nav. Supersonic Lab. at Mach 2.5, 3.0, and 3.5 of heat transfer induced by cooling of the outer surface of the channel wall to ice and dry-ice temperatures producing surface-to-stagnation temperature ratio as low as 0.7, with the recovery factor of 0.89 independent of Mach and Reynolds Numbers; comparison of results with corrected ones of the Van Driest flat-plate constant-surface-temperature theory.

HEAT-TRANSFER MEASUREMENTS IN AN INEXPENSIVE SUPERSONIC WIND TUNNEL. I---APPARATUS AND RESULTS FOR A LAMINAR BOUNDARY LAYER BASED ON A SIMPLE ONE-DIMENSIONAL FLOW MODEL. Joseph Kaye, J. H. Keenan, G. A. Brown, and R. H. Shoulberg. II---RESULTS FOR A LAMINAR BOUNDARY LAYER BASED ON A TWO-DIMENSIONAL FLOW MODEL. Joseph Kaye and G. A. Brown. J. Appl. Mech., Sept., 1955, pp. 289--304. 16 refs. ONR-sponsored experimental investigation at MIT of heat-transfer coefficients for supersonic air flow in a round tube, with detailed test data on laminar, transitional, and turbulent boundary layers for Mach Numbers at the tube inlet of 2.8 and 3.0, and with the range of values of diameter Reynolds Numbers between 20,000--100,000 and the length Reynolds Numbers up to about 4,000,000; comparison of analytical results with theoretical predictions for flow in the entrance region of a tube in the presence of a laminar boundary layer.

HYDRODYNAMIC STABILITY. Appendix A---ASYMPTOTIC SOLUTIONS. Appendix B---METHOD OF INTEGRATION OF THE INVISCID ORR-SOMMERFELD EQUATION. Appendix C---SOME OBVIOUS EXTENSIONS OF THE STABILITY OF PLANE PARALLEL FLOWS. Appendix D. Martin Lessen, H. G. Lew, S. I. Pai, J. B. Fanucci, and J. A. Fox. Penn. State U. Dept. Aero. Eng. TR 2, May, 1954. 88 pp. 55 refs. ONR-sponsored investigation of quasi-parallel flows with infinite boundaries taking into account the eigenvalue problem associated with the Orr-Sommerfeld equation for the cases of the two-dimensional jet using the variational and Galerkin methods and the axially symmetric jet subjected to rotationally symmetric disturbances, with the inviscid eigenvalues for the full and half jet explored by numerical methods.

AN INVESTIGATION ON FULLY DEVELOPED TURBULENT FLOWS IN A CURVED CHANNEL. Salamon Eskinazi and Hsuan Yeh. J. Aero. Sci., Jan., 1956, pp. 23--34, 75. 13 refs. ONR-spon-

sored measurements at Johns Hopkins U. in a high-speed wind tunnel of the influence of the channel curvature between circular, concentric walls on mean velocity, turbulence intensity, scale, and spectrum analyzed in terms of the turbulent energy equation, with a comparison to flow conditions at the same Reynolds Number in a straight channel, and with a description of the test equipment.

NOZZLE FLOW WITH HEAT TRANSFER AND FRICTION; ONE-DIMENSIONAL EXPANSION OF A COMPRESSIBLE FLUID IN A CONVERGENT NOZZLE WITH HEAT FLOW AND FRICTION. W. Gordon Watson. Aircraft Eng., Oct., 1955, pp. 339--345. 12 refs. Analysis of the problem of choking under varying conditions for the case of critical velocity of a pressure change at the throat of a convergent-divergent nozzle, setting aside the aspect of acoustic velocity as the special case of the critical velocity where the expansion in the nozzle is isentropic.

Wings & Airfoils

CALCULATED SPANWISE LIFT DISTRIBUTIONS AND AERODYNAMIC INFLUENCE COEFFICIENTS FOR SWEPT WINGS IN SUBSONIC FLOW. Franklin W. Diederich and Martin Zlotnick. U.S., NACA TN 3476 (Suppl. to NACA TN 3014), Oct., 1955. 173 pp. Measurements using the Weissinger method with eight control points on the semispan on 61 plan forms with various aspect and taper ratios, and with a variety of angle-of-attack or twist distributions, including flap and aileron deflections; includes calculations of the influence coefficients for a definite set of stations along the span to be used in the analysis of untwisted wings or wings with known twist distributions and for aeroelastic determinations involving initially unknown twist distributions.

THE CALCULATION OF THE WAVE DRAG OF AN ARBITRARY SLENDER BODY BY MEANS OF AN ELECTRICAL ANALOGY TANK. P. J. Pocock. Can. Aero. J., Nov., 1955, pp. 168--177. 15 refs. NAE experimental investigation using a Malavard "wing calculator" type tank based on the analogy between the supersonic wave drag and the subsonic induced drag of an "equivalent" lifting line, with a comparison to the direct integration, Sears, and Routledge-Lord-Eminton methods, and with an appraisal of the tank design, operating characteristics, and potentialities.

MEASUREMENTS OF THE EFFECT OF TRAILING-EDGE THICKNESS ON THE ZERO-LIFT DRAG OF THIN LOW-ASPECT-RATIO WINGS. John D. Morrow. (U.S., NACA RM L50F26, 1950.) U.S., NACA TN 3550, Nov., 1955. 11 pp. Free-flight investigation of rocket-powered drag-research models of tapered 4-percent-thick wings with an aspect ratio of 3.11 and trailing-edge thicknesses of 0, 1/3 maximum, 2/3 maximum, and maximum at Mach Number range of 0.7--1.6 to determine the corresponding increase in wing drag coefficient throughout the Mach range due to the greater area over which the base suction acts.

SOME EFFECTS OF VISCOSITY ON WING-BODY INTERFERENCE AT M = 1.9. T. R. Rhees and W. P. Crenshaw. J. Aero. Sci., Jan., 1956, pp. 43--48. 11 refs. Results of experiments in the U. Mich. Intermittent-Flow Supersonic Wind Tunnel on a flat rectangular wing-cylindrical body combination with a laminar boundary layer compared with those for the turbulent case on the same body and the predictions of the NACA linearized inviscid theory, taking into account a qualitative similarity of the shock-wave and laminar boundary-layer interaction to the two-dimensional case and the problem of lift loading due to interference for such bodies as missiles with wings or control surfaces near the tail.

THE SUPERSONIC CONICAL WING OF MINIMUM DRAG. S. H. Tsien. J. Aero. Sci., Dec., 1955, pp. 805--817, 843. 18 refs. USAF-supported theoretical investigation at Cornell U. Grad. Sch. of Aero. Eng. of three-dimensional optimum-lifting thin wings of the conical family with subsonic leading edges cambered to give minimum pressure drag at supersonic speeds, taking into account the effect of chordwise camber of parabolic shape; analysis includes a development of an approximate method based on the linear small-perturbation theory, an approximation to the lift distribution in series form, and two assumptions for leading-edge suction dealing with the full conceptual values of the thrust component and a no-thrust component representing an extreme case of full separation at the leading edge.

A THEORETICAL INVESTIGATION OF THE DRAG OF GENERALIZED AIRCRAFT CONFIGURATIONS IN SUPERSONIC FLOW. Appendix V ---DISTRIBUTION OF LIFT IN A TRANSVERSE PLANE FOR MINIMUM VORTEX DRAG. Appendix VI---DERIVATION OF OPTIMUM DISTRIBUTION OF LIFT THROUGH A SPHERICAL SPACE. E. W. Graham, P. A. Lagerstrom, R. M. Licher, and B. J. Beane. Douglas Rep. SM-19181, July, 1955. 121 pp. 21 refs. Analysis includes: singularities used in the "linearized" description of flow about aircraft; evaluation of drag; criteria for determining optimum distributions of lift or volume elements alone; an investigation of separability of lift, thickness, and sideforce problems; and uniqueness problems for optimum spatial distributions, in terms of such a property as the interference between lift and thickness distributions used.

AEROELASTICITY

COMPUTATION OF VIBRATION MODES AND FREQUENCIES ON SEAC. W. F. Cahill and Samuel Levy. J. Aero. Sci., Dec., 1955, pp. 837--843. Development of general Standards Eastern Automatic Computer codes based on the modified Kincaid matrix iteration scheme for symmetric and antisymmetric modal flutter and dynamic analyses of aircraft structures, taking into account specified influence coefficients, mass

distribution, and geometry.

ÉTUDE DE L'AMORTISSEMENT DES VIBRATIONS EN VOL PAR PERCUSSIONS SUR LES SURFACES PORTANTES. G. Coupry, R. Valid, and G. Piazzoli. La Recherche Aéronautique, Sept.-Oct., 1955, pp. 37--42. In French. Flight measurements using spectrographic techniques of oscillation damping by percussion on lifting surfaces, taking into account nonstationary aerodynamic motions and characteristic parameters to determine structural responses.

ÉTUDE DES VIBRATIONS AÉROÉLASTIQUES DES GOUVERNES EN SUBSONIQUE ÉLEVÉ. A.-G. Meller and A. Berton. La Recherche Aéronautique, Sept.-Oct., 1955, pp. 27--35. In French. Experimental study using NACA 66 008 type models of aeroelastic vibration controls in high subsonic two-dimensional flows, taking into account the effects of wind-tunnel walls, with an analytical comparison to theoretical predictions.

JUSTIFICATION D'UNE APPROXIMATION DES FORCES AÉRODYNAMIQUES VIBRATOIRES EN ÉCOULEMENT SUBSONIQUE TRIDIMENSIONNEL. J. Legras. La Recherche Aéronautique, Sept.-Oct., 1955, pp. 21--26. In French. Applicability of an approximation method to calculate the vibrational aerodynamic forces in three-dimensional subsonic flow, with a formulation of the oscillating lifting-surface equation indicating the continuity between the constant and nonstationary flow problems, and providing for a static span correction for the case of reduced frequency within the theory of longitudinal wing sections in constant flow.

MÉTHODE D'ANALYSE GRAPHIQUE DE LA RÉSULTANTE DE DEUX VIBRATIONS SINUSOIDALES AMORTIES. H. Loiseau and R. Dat. La Recherche Aéronautique, July-Aug., 1955, pp. 43--49. In French. A rapid graphic method to analyze periodic phenomena resulting from the superposition of two damped sinusoidal vibrations of different harmonic periods in the determination of each of the frequencies as used for the study of damping of aircraft or dynamic models.

MÉTHODE PRATIQUE DE DÉTERMINATION DE LA COURBE D'ÉVOLUTION THÉORIQUE DU FLOTTEMENT DE GOUVERNE A UN DEGRÉ DE LIBERTÉ. C. Béatrix. La Recherche Aéronautique, July-Aug., 1955, pp. 51--55. In French. Simple and rapid method to determine the theoretical evolutionary flutter curve for the control and damping of oscillations of one degree of freedom at transonic and supersonic velocities.

SIMULATEUR POUR L'ÉTUDE EN LABORATOIRE DE LA RÉPONSE D'UNE STRUCTURE À UNE EXCITATION PAR UNE OU PLUSIEURS IMPULSIONS DE FORMES VARIABLES. P. Mathon. La Recherche Aéronautique, July-Aug., 1955, pp. 39--42. In French. Laboratory apparatus to study response of dynamic structural systems of one or several degrees of freedom and to determine optimum variable impulse simulation for flight testing.

SYSTEM MODE SHAPES IN THE FLUTTER OF COMPRESSOR BLADE ROWS. Frank Lane. J. Aero. Sci., Jan., 1956, pp. 54--66. USAF-sponsored development at NYU of an analytical method to determine the flutter-inception point in predicting the critical velocity or rotational speed under the assumption of infinite rotor inertia or constant rotor velocity, with an extension to the case of torsional oscillations of the rotor; potential practical application to stall-flutter analysis.

SYSTÉMATISATION DU CALCUL DES VIBRATIONS PROPRES D'UNE STRUCTURE QUELCONQUE LIBRE OU PARTIELLEMENT MAINTENUE PAR UN BATI FIXE À PARTIR DE COEFFICIENTS D'INFLUENCE. D. Clerc and R. Kappus. La Recherche Aéronautique, July-Aug., 1955, pp. 31--38. In French. Systematized vibrational analysis of frequency modes and pulsations of a free or partially supported fixed-frame structure to determine basic matrices reflecting the geometry and the dynamic and elastic characteristics and secondary matrices for the influence coefficient.

TURBULENCE ENCOUNTERED BY COMET I AIRCRAFT. Appendix I---METHOD OF TRANSLATING ACCELERATION INTO GUST SPEED. J. R. Heath-Smith. Gt. Brit., RAE Rep. Struc. 179, May, 1955. 26 pp., folded tables. BOAC acceleration operational records of gusts encountered en route, with a description of flight apparatus and instrumentation.

VIBRATIONS OF ELASTIC SYSTEMS UNDER INITIAL STRESS. George H. Handelman. Carnegie Inst. Tech. TR 4 (OSR TR 55-28), Sept., 1955. 10 pp. Investigation featuring the analysis of the effects of high rotational speeds on beam-like structures, the attachment of rigid masses, and the presence of flowing fluids.

AERONAUTICS, GENERAL

CURRENT TRENDS IN RESEARCH AND PROCUREMENT IN THE U.S. TODAY. I---SELECTED LIST OF CURRENTLY ACTIVE AND RECENTLY COMPLETED MANUFACTURING METHODS RESEARCH PROJECTS (AIR MATERIEL COMMAND). II---CURRENTLY ACTIVE RESEARCH PROJECTS IN UNITED STATES ENGINEERING COLLEGES. Aero Dig., Oct., 1955, pp. 66 (10 ff.) Survey data broken down by types of projects and by institutions based on AMC, Wright-Patterson AFB and NYU Eng. Res. Council reports.

AIR TRANSPORTATION

COOPERATION IN AIR TRANSPORT; NEW MEDIUM-RANGE AIRLINERS. Interavia, Oct., 1955, pp. 749--781, cutaway drawings. Partial contents: Thoughts on Strasbourg; The First European Civil Aviation Conference: A Challenge to Europe, L. H. Slotemaker. Cooperation, Willem Deswarte. Turbine Air Transportation One Step Over the Threshold; A Critical Review of Papers Presented at the Seattle Meeting of the

Institute of the Aeronautical Sciences, August 8--10, 1955, Maurice A. Garbell. New Aircraft for Short and Medium Stages: Comet 4---Caravelle---Viscount 800---Electra---Friendship---Accountant---HD.32/321---Herald---Convair 440.

COMPUTERS

ANALOG MEASUREMENT AND CONVERSION TO DIGITS. T. C. Fletcher and N. C. Walker. ISA J., Sept., 1955, pp. 341--345. 86 refs. Basic principles, design, and potentialities of voltage converter systems featuring repeatability of one part per thousand to provide operational means of converting input voltage to mechanical position of a code plate, substracting reference voltages in decreasing magnitudes from the input by use of relays, and comparing the voltage with a time-varying reference, with a comprehensive bibliography; applications.

COMPUTATIONS IN AIRCRAFT DESIGN. B. Langefors. Saab Sonics, No. 23, 1955, pp. 8--16, 25. Operational principles of automatic high-speed methods and apparatus providing for data processing, matrix analysis, and rational or tabular representation.

THE DESIGN OF A BASIC ELECTRIC-TANK ANALOGY INSTALLATION. W. B. Brower, Jr., and P. DeRienzo. Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE5505, Sept. 1, 1955. 9 pp. USAF-sponsored development of mechanical and electrical analogical apparatus for use in two-dimensional flow studies, with descriptive details of circuits and components.

A NINE'S COMPLEMENT DECADE COUNTER AND RECORDER. J. A. Phillips. Australia, ARL IN 55, Apr., 1955. 22 pp. Design, operation, and potentialities of a binary circuit for the ARL Multichannel Digital Strain Recorder to present results in terms of positive or negative decimals, with construction details.

ELECTRONICS

FROM LINEAR MECHANICS TO NONLINEAR MECHANICS. Julien Loeb. (An. Télécomm., Paris, Feb., 1950, pp. 65--71.) U.S., NACA TM 1396, Oct., 1955. 18 pp. Translation. Application of telecommunication principles to the development of a method for the linearization of nonlinear electromechanical control devices in which a sweep function acts as a carrier wave in radio-electricity.

THE RO-DR COMPUTER SYSTEM. W. F. Haehnel and J. L. McKelvie. Can. Aero. J., Nov., 1955, pp. 183--191. Design and operational principles of the automatic ground-position computer developed by PSC Applied Research Ltd. for high-speed, all-weather navigation during patrol and interception flights.

EQUIPMENT

PROBLEMS OF MOVEMENT IN DUCTING SYSTEMS. P. E. W. Chorley. J. SLAE, Sept., 1955, pp. 2--5. Appraisal of design requirements of pressure, temperature, materials, and construction; applications include shaft seals and pressure-sensitive devices such as control valves and pressure switches for fuel tanks, cabin or cockpit pressurization and air conditioning, and de-icing and de-misting systems.

SOME TRENDS IN THE DEVELOPMENT OF AIRCRAFT ELECTRICAL AND STARTING SYSTEMS. R. H. Woodall. J. RAeS, Sept., 1955, pp. 587--603. Design requirements and problems related to high altitudes and supersonic speeds in terms of reliability, efficiency, and weight factors, taking into account the need for constant-frequency a.c. supplies and the limitations of static and ram-air cooled equipment and such components as brushes, bearings, seals, and hydro-mechanical drives.

ICE FORMATION & PREVENTION

DEVELOPMENT AND TEST OF A COOLED ROTATING DISC ICING METER. Appendix I---THE THICKNESS OF ICE FORMED ON A ROTATING DISC. F. J. Bigg. Gt. Brit., RAE TN Mech. Eng. 200, Mar., 1955. 21 pp. Design and operational application; includes flight test results and details of a cooling method.

INSTRUMENTS

GRAPHICAL AIDS FOR FREQUENCY RESPONSE ANALYSIS. H. D. Eckhardt. J. Aero. Sci., Jan., 1956, pp. 83--86. Use of a template for the direct construction or modification of "gain-phase" plots of the logarithm of the amplitude ratio of the frequency response of a system versus the phase angle of that response as a function of frequency to determine the behavior of closed-loop dynamic systems such as servomechanisms.

LES IDÉES FONDAMENTALES DE LA THÉORIE DES SERVOMÉCANISMES. H. Le Boiteux and R. Moreau. La Recherche Aéronautique, Sept.-Oct., 1955, pp. 47--54. In French. Fundamental theoretical principles and characteristics of servomechanisms analyzed in terms of the factors of permanent rate, damping, sensitivity, response, dynamic stability, efficiency, and reliability.

A SURVEY OF SOME RECENT DEVELOPMENTS IN THE AUTOMATIC CONTROL FIELD. John A. Hrones. Appl. Mech. Rev., Dec., 1955, pp. 501--504. 10 refs. Application of feedback principles to the design of high performance servos and other control devices, taking into account system parameters, moment of inertia, damping ratio, reference input, and transient or disturbance response.

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SHORTCOMINGS OF PRESENT METHODS OF MEASURING AND SIMULATING VIBRATION ENVIRONMENTS. C. T. Morrow and R. B. Muchmore. (ASME Diamond Jubilee Semi-Annual Meeting, Boston, June 19--23, 1955, Paper 55-SA-2.) J. Appl. Mech., Sept., 1955, pp. 367--371. Analysis of measurement problems for delicate instrumentation or electronic devices used in the field and for simulation of specialized conditions in laboratory testing of reliability factors of design.

MATERIALS

ON THE DUALISM IN THE FRACTURE THEORY. Masakazu Higuchi. Kyushu U., Japan, Rep. Res. Inst. Appl. Mech., Mar., 1955, pp. 155--169. 15 refs. Theoretical and experimental analysis of the phenomenal behavior of the microstructure to formulate a concept of the dualistic strength property of plastics, with an extension applied to simple cases of loading of specimens.

Metals & Alloys

COLUMN CURVES FOR TYPE 301 STAINLESS STEEL. E. W. Hammer, Jr., and R. E. Petersen. Aero. Eng. Rev., Dec., 1955, pp. 33--39. Tests at the Franklin Inst. Labs. for Res. & Development on annealed specimens and for samples of varying degrees of hardness to determine use of the reduced or tangent modulus theory in the calculation of critical column loads for the development of design specification criteria, taking into full account the nonvalidity for stainless steel of the Euler equation $P/A = \pi^2 E/(L/\rho\sqrt{c})^2$ intended for maximum apparent stress of a column with stable cross section for materials stressed below the proportional limit.

DE INVLOED VAN TEMPERATUURVERHOGING TOT ONGEVEER 450° C OP DE MECHANISCHE EIGENSCHAPPEN VAN DE CONSTRUCTIEMATERIALEN: ALUMINIUMLEGERINGEN, ROESTVRIJ STAAL, TITAAN EN TITAANLEGERINGEN (THE INFLUENCE OF ELEVATED TEMPERATURES UP TO 450° C ON THE MECHANICAL PROPERTIES OF ALUMINUM ALLOYS, STAINLESS STEEL, TITANIUM, AND TITANIUM ALLOYS). A. Hartman. Netherlands, NLL Rep. M.1987, June 14, 1955. 86 pp. 92 refs. In Dutch. Review of the literature, with an analysis of material characteristics and potentialities for aircraft applications.

METAL FATIGUE: A BIBLIOGRAPHY OF UNPUBLISHED REPORTS. Gt. Brit., MOS TIB/BIB (U)/4, Aug., 1955. 23 pp. 305 refs. Chronological arrangement covering properties of: Aluminum, steel and iron, and other metals and alloys; sandwich construction; corrosion fatigue; tests on joints and fasteners; testing apparatus for aircraft and components.

ULTRA-HIGH STRENGTH STEELS. G. Meikle. Gt. Brit., RAE TN Met. 221, May, 1955. 8 pp. Brown-Firth, Fairey, and RAE tests on steels of over 100 tons per sq. in. U.T.S.

THEORY OF DYNAMIC CREEP (K TEORII DINAMICHESKOI POLZUCHESTI). A. A. Predvoditelev and B. A. Smirnov. (Vestnik Moskovskogo U., Phys. Mat. Nat. Sci., No. 8, 1953.) U.S., NACA TM 1330, Sept., 1955. 12 pp. Translation. Analytical development based on the Becker after-effect calculations of the metallic creep deformation phenomena under dynamic loadings, taking into account theoretical instantaneous creep rate dependent on the magnitude of the instantaneous stress and on the rate of change of the stress, the effect of cyclic stresses on metallurgical changes in the acceleration of such factors as aging and recrystallization, and dynamic loads that facilitate or give rise to slip and other forms of lattice deformation.

ALUMINUM ALLOYS FOR ELEVATED TEMPERATURE SERVICE. E. H. Dix, Jr. (CAI-IAS Internatl. Meeting, Ottawa, Nov. 3, 4, 1955, Preprint 574.) Aero. Eng. Rev., Jan., 1956, pp. 40--48, 57. Experimental data on new alloys of the 7075-T6, 2024-T4, 2014-T6, 2618-T61, M237, X2219-T6, XA140, A355, and APM groups relating such physical, mechanical, and fabricational properties as forming, casting, elasticity modulus, aging, creep, rupture, and tensile yield strength at varying temperatures to structural problems of buckling, fatigue, corrosion, and thermal stress.

ALUMINUM ALLOYS FOR ELEVATED TEMPERATURE SERVICE. E. H. Dix, Jr. (CAI-IAS Internatl. Meeting, Ottawa, Nov. 3, 4, 1955, Preprint 574.) Aero. Eng. Rev., Jan., 1956, pp. 40--48, 57. Physical and fabricational properties, with results of tests on 7075-T6, 2024-T4, 2014-T6, and other alloys.

TRIXIAL PLASTIC STRESS-STRAIN RELATIONS FOR AN ALUMINUM ALLOY 14S-T4. Joseph Marin and H. A. B. Wiseman. J. Franklin Inst., Nov., 1955, pp. 397--409. OOR-sponsored investigation to determine the validity of theoretical principles of simple plastic flows using constant stress ratios.

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CLEAR AIR TURBULENCE AND CIVIL JET OPERATIONS. E. Chambers. J. RAeS, Sept., 1955, pp. 613--628. 19 refs. Statistical analysis and review of USAF, NavBuAer, NACA, RAE, RAF, RAAF, BEA, and other investigations and

of BOAC experience, with meteorological charts and tables covering the jet-stream phenomena, gusts, and imposed stress.

MISSILES

HISTORY, PROBLEMS, AND STATUS OF GUIDED MISSILES. George P. Sutton. Jet Propulsion, Nov., 1955, pp. 615--622. 18 refs. Developmental appraisal of American and foreign progress and design trends, with an evaluation of such aspects as structural components, propulsion, guidance, control, power-supply, target acquisition and identification, launching and handling equipment, inherent flexibility, reliability versus complexity, and testing.

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INERTIAL NAVIGATION. J. M. Slater and D. B. Duncan. Aero. Eng. Rev., Jan., 1956, pp. 49--52, 57. Appraisal of basic principles and limitations compared to celestial and dead-reckoning modes of navigation, with a method to determine vehicle position by acceleration and velocity measurements.

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OPTICAL CHARACTERISTICS OF LAMINATED CAMERA WINDOWS. A. C. Marchant and B. M. Mathieson. Gt. Brit., ARC CP 210, 1955. 23 pp. 10 refs. BIS, New York. $ 0.65. Tests to develop criteria for shattering- and pressure-resistant requirements of higher air-speeds.

POWER PLANTS

NUCLEAR PROPULSION, AVIATION'S FUTURE. D. G. Samaras. Can. Aero. J., Nov., 1955, pp. 163--168. Developmental appraisal of various modes of propulsion using extra-nuclear and nuclear fuels to obtain maximum performance potentialities for visualized terrestrial, interplanetary, and intragalactic flight.

TWENTY-FIVE YEARS OF ROCKET DEVELOPMENT. Howard S. Seifert. Jet Propulsion, Nov., 1955, pp. 594--603. 71 refs. Evolutionary survey of experimental and theoretical investigations featuring gaseous-, liquid-, and solid-propellant and nuclear-powered engine designs, with an analysis of relative performance potentialities in terms of operational requirements, taking into account such factors as structural weights, range, payload, ballistic accuracy, reliability, simplicity, flow geometry and dynamics, combustion chamber and nozzle design, ignition control, and fuel characteristics.

Jet & Turbine

APPLICATION OF SOME SYSTEMS ENGINEERING PRINCIPLES TO THE DESIGN OF A FUEL-SUPPLY SYSTEM. A. E. Buescher and G. J. Fiedler. (ASME Diamond Jubilee Semi-Annual Meeting, June 19--23, 1955, Paper.) ISA J., Sept., 1955, pp. 352--360. Analysis of illustrative problems as developed for a test ramjet or turbojet engine facility, with a derivation of a mathematical relationship between flow and pressure and the optimum mode of control, taking into account control-valve location and requirements of performance, operating conditions, and space limitations.

A CASE FOR SMALL TURBINE ENGINES. J. J. Eden. Can. Aero. J., Oct., 1955, pp. 141--147. Analysis of the relative merits of the small designs in terms of performance, weight, fuel consumption, maintenance, and reliability requirements, especially taking into account installation, automatic temperature and speed controls, and the use of multi-indicator instruments for scatter indication; applications include assisted and vertical take-off and landing units, helicopter propulsion, engine starters, boundary-layer and circulation control, and accessory drives.

THE DEVELOPMENT AND FUTURE OF TURBINE ENGINES FOR CIVIL AIRCRAFT. J. D. PEARSON. First Albert Plesman Memorial Lecture, Tech. U., Delft, Pamphlet, Sept. 12, 1955. 51 pp. Includes analyses of the Rolls-Royce Dart and RB.109 designs in terms of performance ratings, reliability, testing requirements, and potentialities, taking into account the factors of planning and research, metallurgical progress, operational life and maintenance, anti-icing and de-icing equipment, flight endurance, speed and altitude ratings, fuel consumption, braking and control systems, means of fire prevention, design of specialized components, and mechanical rig testing, with an appraisal of the turboprop versus turbojet issue.

HIGH TAILPIPE MACH NUMBERS IN REHEATED TURBOJET ENGINES. E. P. Cockshutt, Can. Aero. J., Oct., 1955, pp. 130--136. Evaluation of the importance of the gas Mach Number in relation to the size and thrust of the power plant, with a formulation of a criterion for the maximization of thrust per unit frontal area and a qualitative appraisal of the effects of tailpipe Mach Number changes on the combustion process.

PROGRESS IN DEVELOPMENT OF A RIG FOR TESTING VARIABLE AREA EXHAUST NOZZLES FOR TURBOJET ENGINES FITTED WITH AFTERBURNERS. Appendix A---VARIABLE AREA NOZZLE TESTS. R. J. T. Bruce and J. C. Vrana. Canada, NAE LR-135, May 25, 1955. 12 pp., 14 plates. Includes descriptive details of the preheat combustion chamber design, air atomizing nozzle, main fuel injector for the afterburner, control cabin and instrumentation, air centrifugal compressor, and fuel supply components, with test results.

THE 600 H.P. OVERSPEED AND BURSTING RIG AT N.G.T.E., PYESTOCK. T. M. Jones

and R. L. Brooking. Gt. Brit., NGTE Memo. M. 249, Sept., 1955. 10 pp. Design and installation features of the spinning rig for tests on gas-turbine components.

ACOUSTIC ANALYSIS OF RAM-JET BUZZ. Harold Mirels. U.S., NACA TN 3574, Nov., 1955. 33 pp. 13 refs. A one-dimensional analysis of the mechanism leading to buzz as the amplification of acoustic waves in the ram-jet combustion chamber due to successive reflections from the inlet and exit sections.

STUDY OF SCREECHING COMBUSTION IN A 6-INCH SIMULATED AFTERBURNER. Appendix A. Appendix B---DISTORTION AND DIMINUTION OF SOUND WAVES OF FINITE AMPLITUDE IN TUBES. P. L. Blackshear, W. D. Rayle, and L. K. Tower. U.S., NACA TN 3567, Oct., 1955. 58 pp. 14 refs. Development of probe microphones and instrumentation to measure frequency, relative amplitude, and phasing of the pressure oscillations in a combustor, with a derivation of a theory to account for the nonlinear attenuation of high-amplitude sound in tubes, and with an analysis of the acoustic oscillations as the first transverse mode in hot gases downstream of the flameholder.

TWENTY-FIVE YEARS OF RAMJET DEVELOPMENT. William H. Avery. Jet Propulsion, Nov., 1955, pp. 604--614. 94 refs. NAVORD-sponsored analytical review of experimental and theoretical investigations of fundamental design problems covering such factors as fuel characteristics, injection, distribution, metering, control and specific impulse, altitude limits and speed, thrust per unit frontal area and weight, combustor and diffuser designs, efficiency, reliability, design simplicity and flexibility, cost, and engine performance capabilities as compared to other types of jet propulsion units, with a comprehensive bibliography; applications include antiaircraft guided missiles, target drones, nuclear reactors, and long-range bombers.

PRODUCTION

INVESTIGATIONS AND STUDIES ON METAL BONDING AGENTS (UNTERSUCHUNGEN UND STUDIEN ZUM METALLKLEBEN). G. Kaliske. (Aluminium, Düsseldorf, No. 4, 1955, pp. 151--156.) Gt. Brit., RAF Lib. Transl. 552, Oct., 1955. 15 pp. 30 refs. Basic principles of adhesion, bonding techniques, and requirements of bonded joints, taking into account the factors of overlap, tensile strength of materials, thickness of sheets, surface conditions, and testing, and using Araldite XV and 101, Redux epoxy resin Ku9517, and a phenol type Ka 1559 K on aluminum, magnesium, copper, and steel alloys.

THE PRODUCTION OF LARGE FORGINGS IN ALUMINIUM ALLOYS. C. Smith and J. Crowther. J. RAeS, Sept., 1955, pp. 604--612. Methods and types of forgings, taking into account heat-treatment effects on mechanical and residual stresses, resistance to corrosion, design factors, and testing of machined components.

TESTING AND INSPECTION OF WELDS IN ALUMINIUM AND ALUMINIUM-ALLOY PLATE MADE BY THE INERT-GAS-SHIELDED WELDING PROCESSES. P. Bradley. Brit. Welding J., Oct., 1955, pp. 459--463. Details of the qualification and radiographic detection test procedures, with results showing the nature and frequency of typical defects of inclusions, cavities, and fissures under corrosive conditions.

INERT-GAS SHIELDED-ARC WELDING IN THE GAS-TURBINE INDUSTRY. F. G. C. Sandiford, R. T. Weatherstone, J. E. Hooper, K. H. McDowell, and L. Camidge. Brit. Welding J., Oct., 1955, pp. 443--455. Developmental review in terms of exacting aircraft fabricational requirements, with an appraisal of the trend and of the relative merits of the technique, materials, tooling, equipment, inspection, and quality control as related to improved design criteria of strength and weight ratios.

ROTATING WING AIRCRAFT

THE COMPARATIVE PERFORMANCE OF HELICOPTERS, CONVERTIPLANES, AND SLOW-FLYING AIRPLANES. Paul E. Hovgard. Aero. Eng. Rev., Dec., 1955, pp. 40--44. Study of the potentialities of convertiplanes in terms of acceptable performance criteria of related aircraft designs used for carrying passengers and cargo over medium ranges, with computations of required power and weight estimates for each type broken down by structural and engine components.

DESIGN, DEVELOPMENT, PRODUCTION AND SERVICING OF ROTOR BLADES. R. A. Price and F. L. Stulen. J. Helicopter Assn. Gt. Brit., Oct., 1955, pp. 281--294; Discussion, pp. 294--301. Analysis of problems in terms of weight and loading, horizontal thrust, balance control-regulation, structural, aerodynamic, maintenance, fabricational, installation, and other requirements.

HELICOPTER INSTRUMENT FLIGHT AND PRECISION MANEUVERS AS AFFECTED BY CHANGES IN DAMPING IN ROLL, PITCH, AND YAW. J. B. Whitten, J. P. Reeder, and A. D. Crim. U.S., NACA TN 3537, Nov., 1955. 14 pp. Operational study of flying qualities of the single-rotor design using visual maneuvers and electronic components to vary the damping by producing control inputs proportional to the roll, pitch, and yaw rate in a direction to oppose the angular velocities.

VIBRATIONS OF A HELICOPTER ROTOR-FUSELAGE SYSTEM INDUCED BY THE MAIN ROTOR BLADES IN FLIGHT. M. Morduchow, S. W. Yuan, and H. Reissner. (ASME Diamond Jubilee Spring Meeting, Baltimore, Apr. 18--21, 1955, Paper 55-S-7.) J. Appl. Mech., Sept., 1955, pp. 355--360. USAF-sponsored theoretical

investigation, using a simplified model as a symmetrical plane framework with masses concentrated at the joints, of the hub-fuselage response to harmonic forces, with a derivation of an expression for amplitudes of mass points as functions of the masses and natural frequencies of the hub and fuselage.

WIND TUNNEL TESTS ON A 6 FT DIAMETER HELICOPTER ROTOR. T. B. Owen, R. Fail, and R. C. W. Eyre. Gt. Brit., RAE TN Aero. 2378, May, 1955. 34 pp. Measurements of the thrust, torque, and flapping angle over a range of blade angle, shaft inclination, and tip-speed ratio, with a description of experimental equipment, techniques, and installation of balances, and with data on measurements for tunnel corrections including operating discrepancies for interference effects and blade twisting.

SAFETY

CRASH-FIRE RESEARCH WITH JET AIRCRAFT. I. I. Pinkel. (CAI-IAS Internatl. Meeting, Ottawa, Nov. 3, 4, 1955, Preprint 570.) Aero. Eng. Rev., Jan., 1955, pp. 53--57. Review of NACA investigations using fully instrumented aircraft accelerated from rest under their own power into a crash barrier to determine the damage of spilled fuel in take-off or landing accidents.

SPACE TRAVEL

AN ADJUSTABLE STANDARD ATMOSPHERE, WITH APPLICATION TO GRAVITY-PROPELLED BODIES. Ralph H. Upson. U. Minn. Inst. Tech. Dept. Aero. Eng. RAL EM 43, May, 1955. 51 pp. 21 refs. High-altitude and rarefied atmospheric research into such problems as aerodynamic drag, change of altitude, and return-to-earth of a space rocket or a satellite body, with calculations based on the fundamental assumption of constant temperature gradient within a given atmospheric layer, taking into account the theory of vertically rising or falling bodies; includes detailed measurements of drag in the troposphere and lower stratosphere.

STRUCTURES

ANALYSIS OF THE PLASTIC COLLAPSE OF A CRUCIFORM COLUMN WITH INITIAL TWIST, LOADED IN COMPRESSION. J. F. Besseling. J. Aero. Sci., Jan., 1956, pp. 49--53. Extension of the Onat-Drucker incremental or flow-type theory of plasticity indicating the large influence of very small thus unavoidable imperfections on the ultimate compressive load treating the simplified model's flanges as solid plates to determine, by means of a step-by-step procedure based on an isotropic flow theory, the ultimate compressive stress, with a calculation of its drop caused by increasing compressive strain accompanied by growing twist as part of the interaction between compressive and shear strains in the stress-strain relations for the plastic range.

BUCKLING OF SANDWICH CYLINDERS UNDER COMBINED COMPRESSION, TORSION, AND BENDING LOADS. C. T. Wang, R. J. Vaccaro, and D. F. De Santo. J. Appl. Mech., Sept., 1955, pp. 324--328. ONR-sponsored theoretical investigation, with the governing equation solved by means of the Galerkin method, and with the interrelationship between the critical loads plotted in the form of nondimensional interaction curves.

THE EFFECTIVE WIDTH IN THE PLASTIC RANGE OF FLAT PLATES UNDER COMPRESSION. III. Appendix---THE MAXIMUM LOAD OF FLAT PLATES UNDER COMPRESSION. M. Botman. Netherlands, NLL Rep. S.465, June, 1955. 68 pp. Results of tests on 18 aluminum 75 S-T and 2S-1/2H alloy plates.

FATIGUE TESTS AND AIRCRAFT LIFE EVALUATION ON THE EXPERIMENTAL CORRELATION OF SERVICE ENDURANCE TESTS WITH FATIGUE TESTS AT CONSTANT STRESS AMPLITUDE. Tibor Haas. Aircraft Eng., Oct., 1955, pp. 334--337. 22 refs. Extension of testing methods in terms of the Gassner concept to meet more adequately design and production requirements, with statistical data on fatigue failures related to the program loading principle and the validity of the cumulative damage rule.

AN INVESTIGATION OF THE BENDING OF ANGLE BEAMS IN THE PLASTIC RANGE. Appendix---DERIVATION OF THE EXPONENTIAL EQUATION FOR THEORETICAL BENDING MOMENT OF AN ANGLE BEAM. H. N. Abramson, H. A. Williams, and B. G. Woolpert. J. Aero. Sci., Dec., 1955, pp. 818--828. 17 refs. USAF-supported tests at Stanford U. on 24 S-T aluminum-alloy specimens subjected to bending with the plane of loading at various angles to the minor principal axis of the cross section and the moment applied by means of an eccentric load with a relatively long moment arm; application of the approximate Cozzone and exponential analytical methods for stress-strain relationship to correlate theoretical and experimental bending moments beyond the yield strength under the assumption of a nonrotating, nontranslating neutral axis and a nonrotating cross section.

THE LOCAL INSTABILITY OF A SIMPLE INTEGRAL PANEL. A. H. Chilver. J. RAeS, Oct., 1955, pp. 690--693. Theoretical investigation for the case of the panel subjected to uniform end compression in terms of the problems of interconnected flat plates and of the torsional stability of the stiffeners, with an appraisal of the post-buckling behavior as compared to the Yusuff theory on the primary instability of an integral panel with unflanged stiffeners.

A METHOD OF MEASUREMENT OF ELASTIC AND PLASTIC DEFORMATIONS AND STRESSES IN WELDED JOINTS (MÉTHODE DE MESURES DES DÉFORMATIONS ÉLASTIQUES ET PLASTIQUES ET DES TENSIONS DE SOUDURE). R.

Gunnert. (Arcos, Brussels, No. 121, 1951, pp. 3,027--3,043.) Gt. Brit., RAE Lib Transl. 544, Aug., 1955. 18 pp. Basic principles, development, and relative merits of the method, comparison to the Mathar-Soete, trepanning, and Campus methods, and a description of a high-precision extensometer and other test apparatus; applications and potentialities.

ON THE DANGER OF COMBINED STRESSES IN PRESSURIZED STRUCTURES. M. Zaustin. Aero. Eng. Rev., Dec., 1955, pp. 45--48. Analysis of the causes of the Comet explosive failures, taking into account the cohesive and shear strength of materials, and indicating the need to replace the tensile theory of failure with a more suitable criterion, with illustrative results of tensile strength tests on notched specimens using a theory of stress concentration such as Neuber's.

UNIQUE STRUCTURAL PROBLEMS IN SUPERSONIC AIRCRAFT DESIGN. F. P. Mitchell. (CAI-IAS Internatl. Meeting, Ottawa, Nov. 3, 4, 1955, Preprint 568.) Aero. Eng. Rev., Jan., 1956, pp. 34--39. Analysis of load distribution, wing shape, internal pressures, and landing-gear design in terms of weight requirements of complex low aspect ratio wings and small-diameter fuselage combinations considered as a complete elastic redundant structure, taking into account the dynamics of vibrating systems, fatigue factors, and thermal-stress effects on the strength of materials subjected to aerodynamic heating.

Thermal Stress

THE DETERMINATION OF TEMPERATURE, STRESSES, AND DEFLECTIONS IN TWO-DIMENSIONAL THERMOELASTIC PROBLEMS. B. A. Boley. J. Aero. Sci., Jan., 1956, pp. 67--75. 14 refs. USAF-sponsored development at Columbia U. of an analytical successive-approximation method based on the two-dimensional theory of elasticity to solve linear partial differential equations applied to cases of bars or plates, considered as bodies with one dimension small compared to others, and to establish a thermoelastic theory for material properties given as functions of the temperature; includes: an analysis of the effects of heating on beams evaluating the validity of the Bernouilli-Euler beam-theory hypothesis and extending the fundamental results of von Karman and Seewald; explicit formulas to calculate stresses and deflections; and a detailed table covering equations for the solution of the heat and thermal stress problems.

THE STRUCTURAL EFFECTS OF KINETIC HEATING IN SUPERSONIC FLIGHT. P. B. Walker. J. RAeS, Sept., 1955, pp. 581--586. Study of fundamental principles and of modifications of thermal conditions by insulation and artificial cooling, with a survey of RAE experiments using infra-red, electromagnetic-induction, and other techniques to simulate high-temperature effects such as the deterioration of materials by thermal stress and shock.

TRANSIENT TEMPERATURE DISTRIBUTIONS AND THERMAL STRESSES IN A SKIN-SHEAR WEB CONFIGURATION AT HIGH-SPEED FLIGHT FOR A WIDE RANGE OF PARAMETERS. H. Schuh. (KTH, Stockholm, Aero. Rep. FL 161, 1954?) J. Aero. Sci., Dec., 1955, pp. 829--836, 866. 10 refs. Analytical solutions for cases of continuous variation of parameters using a simple model of an airfoil section consisting of a skin reinforced by shear webs under further simplifying assumptions that the webs are identical and equally placed.

Wings

AN APPROXIMATE NONUNIFORM BENDING THEORY AND ITS APPLICATION TO THE SWEPT-PLATE PROBLEM. H. J. Plass, Jr. J. Appl. Mech., Sept., 1955, pp. 383--388. NAVORD-sponsored theoretical development at the U. of Tex. to determine deflections and stresses in high-speed swept-back wings idealized as a homogeneous isotropic prismatic bar of the same cross section as the wing, with a comparison to experimental results for plates having four different sweep angles.

THE ROOT SECTION OF A SWEPT WING—A PROBLEM OF PLANE ELASTICITY. Appendix ---DIRECT SOLUTION OF BOUNDARY-VALUE PROBLEM. B. C. Hoskin and J. R. M. Radok. J. Appl. Mech., Sept., 1955, pp. 337--347. Investigation using the Muskhelishvili methods of the state of stress and deformation in an approximately square plate having rounded corners under certain shear loading and concentrated forces at the boundary, with the numerical results in the form of tables and charts involving load parameters applied to a wing subjected to varying degrees of torsion and bending.

WEIGHT PREDICTION FOR WINGS OF BOX CONSTRUCTION. Appendix I---WEIGHT OF BENDING MATERIAL. Appendix II---DERIVATION OF PERMISSIBLE COMPRESSIVE STRESS (f_c). Appendix III---WEIGHT OF TORSIONAL COVER. Appendix IV---WEIGHT OF MATERIAL CARRYING DIRECT SHEAR LOADS IN A VERTICAL PLANE. Appendix V---EXAMPLE OF THE METHOD. M. E. Burt. Gt. Brit., RAE Rep. Struc. 186, Aug., 1955. 65 pp., folded charts. 16 refs. Method to obtain wing weights for four structural types based on theoretically derived equations related to project-stage design data.

THERMODYNAMICS

CONVECTION DE JETS D'AIR FRAPPANT NORMALEMENT UNE SURFACE. J. Genot. La Recherche Aéronautique, Sept.-Oct., 1955, pp. 43--46. In French. Study of the convection of identical air jets uniformly distributed and directed normally towards a surface of a heat exchanger to determine a law of distribution of previously set convection coefficients; application to the special case of external-surface cooling of a cylinder

resulting in an equal yield and loss in load, with means to improve the efficiency of the exchanger.

LIQUID-VAPOR PHASE EQUILIBRIUM IN SOLUTIONS OF OXYGEN AND NITROGEN AT PRESSURES BELOW ONE ATMOSPHERE. G. T. Armstrong, J. M. Goldstein, and D. E. Roberts. Appendix---VAPOR PRESSURE OF NITROGEN. G. T. Armstrong. U.S., NBS Rep. 3921, Jan. 31, 1955. 35 pp., folded charts and tables. 15 refs. USAF-sponsored investigation of fundamental properties of air and its component mixtures, with findings applicable to design and construction problems of wind tunnels; includes: a description of the apparatus, test procedures, measuring techniques, and materials used; a calculation of cohesive energy densities of oxygen and nitrogen; and a comparison of experimental and theoretical results.

SURFACE TENSION OF OXYGEN, NITROGEN, AND THEIR MIXTURES. M. L. Reilly and G. T. Furukawa. U.S., NBS Rep. 3958, Feb. 24, 1955. 39 pp. 22 refs. USAF-sponsored study of the properties of air and its components using the capillary rise method, with the density governed by the equation $\gamma \cos \Theta = \frac{1}{2} r (\delta_\ell - \delta_v) gh$, and with the results applicable to wind-tunnel design and comparable to those of the Baly-Donnan theory.

Combustion

ÉTUDE SPECTROGRAPHIQUE DE L'ONDE DE DÉFLAGRATION EN RÉGIME LAMINAIRE. S. Barrère. La Recherche Aéronautique, July-Aug., 1955, pp. 15--24. 14 refs. In French. Spectrographic experiments on laminar flame-front combustion waves for premixed flames of propane, butane, methane, and acetylene combustibles, with data on relative intensities in absorption and emission of various mixing proportions of C_2 and CH radicals.

INSTALLATION D'ESSAI DE FATIGUE À CHAUD EN TRACTION ONDULÉE DANS LES GAZ DE COMBUSTION DE PÉTROLE. G. Vidal. La Recherche Aéronautique, July-Aug., 1955, pp. 25--29. In French. Technique and apparatus for heat-resistant and traction-wave tests on combustion gases of gasoline under controlled atmospheric conditions to study the behavior of an alloy under the combined and simultaneous effects of temperature, alternating stress, and corrosion.

STUDIES OF CHLORINE TRIFLUORIDE FLAMES. G. Skirrow and H. G. Wolfgard. Proc. Royal Soc. (London), Ser. A, Oct. 11, 1955, Fundamental combustion experiments on idealized diffusion flame processes at the RAE Rocket Propulsion Dept., with a comparison to the Durie spectrographic results on flame characteristics, structure, and stability.

WATER-BORNE AIRCRAFT

HOPE FOR RATIONAL SEAPLANE DESIGN. J. D. Pierson and C. E. Carver, Jr. Aero. Eng. Rev., Dec., 1955, pp. 26--30. 13 refs. Results of hydrodynamic analyses by Sverdrup-Munk, Johnson-Rice, Lonquet-Higgins, Neumann, Fuchs-MacCamy, St. Denis-Pierson, and others of such phenomena as waves, current, and meteorological influences on the sea surface applied to design problems of structural failures and responses to wave impacts as recorded with accelerometers, pressure-type instruments, and radar-echo-return measuring devices, with mathematical models and statistics used to study harmonic wave data.

WIND TUNNELS & RESEARCH FACILITIES

AERONAUTICAL RESEARCH IN SWEDEN. Bo K. O. Lundberg. J. RAeS, Oct., 1955, pp. 647--677; Discussion, pp. 677--681. 67 refs. Review of FFA investigations in the basic and applied fields of aerodynamics and structures and related areas of measuring techniques, with design and operational data on different types of wind tunnels, testing facilities, and instrumentation for low-speed, subsonic, and supersonic experimentation.

LE DÉCOLLEMENT LAMINAIRE EN TROIS DIMENSIONS. E.-A. Eichelbrenner and A. Oudart. La Recherche Aéronautique, Sept.-Oct., 1955, pp. 11--14. Experimental investigation in the Chatillon hydrodynamic wind tunnel of three-dimensional laminar separation governed by the condition

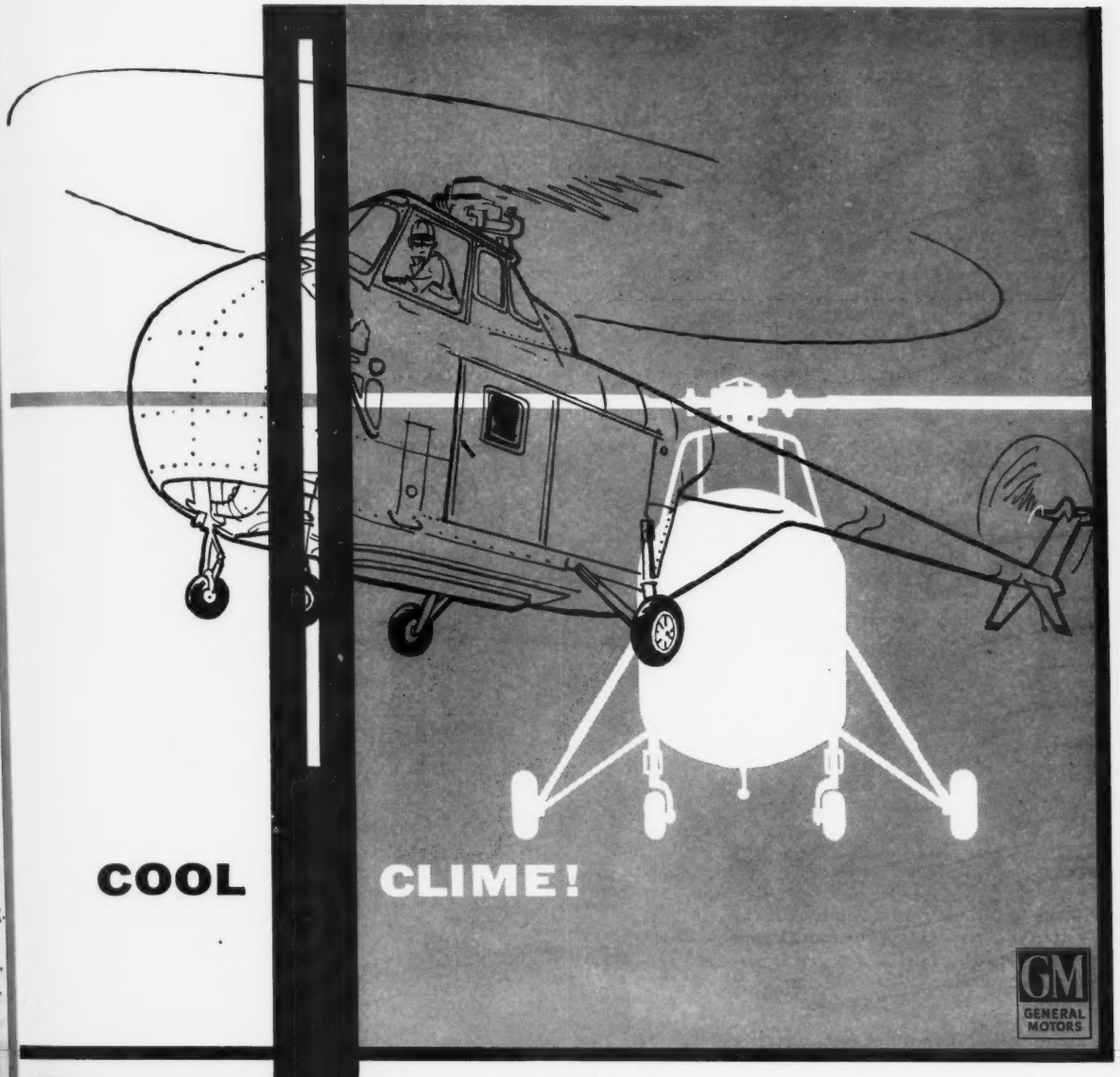
$$\left(\frac{d\,v}{d\,n}\right)_p = 0$$

applied to the cases of an infinite side-slipping cylinder and an ellipsoid body of revolution inclined with regard to the wind.

EXPERIMENTS ON A SLOTTED-WALL WORKING SECTION IN A WIND TUNNEL. F. Vandrey and K. Wieghardt. Gt. Brit., ARC CP 206 (Mar. 18, 1952), 1955. 17 pp. BIS, New York. $ 0.50. Development for a water tunnel with correction properties of a free jet for the testing of long streamlined bodies of revolution.

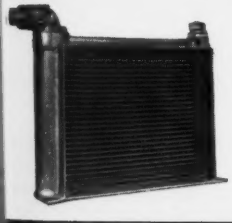
THE FLAT PLATE WITH AN ANGLE OF ATTACK IN A CHOKED WIND TUNNEL. K. G. Guderley. J. Aero. Sci., Dec., 1955, pp. 844--866. Extension of the Marschner investigation indicating the small wall influence on the pressure distribution over a wedge in transonic wind-tunnel testing, taking into account boundary conditions at the plate and at the walls.

ON THE THEORY OF SHOCK REFLECTION ON WALLS WITH SLOTS. W. Eckhaus. Netherlands, NLL Rep. F.167, July 25, 1955. 20 pp. Derivation of conditions to ensure complete cancellation of reflected disturbances at an infinitely large distance from a wind-tunnel wall, taking into account the relations of an oblique shock interacting with the Prandtl-Meyer expansion flows and the mechanism of shock reflection on walls with transversal or longitudinal slots calculating the ratio of open to total wall area.



COOL CLIME!

GM GENERAL MOTORS



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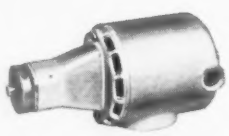

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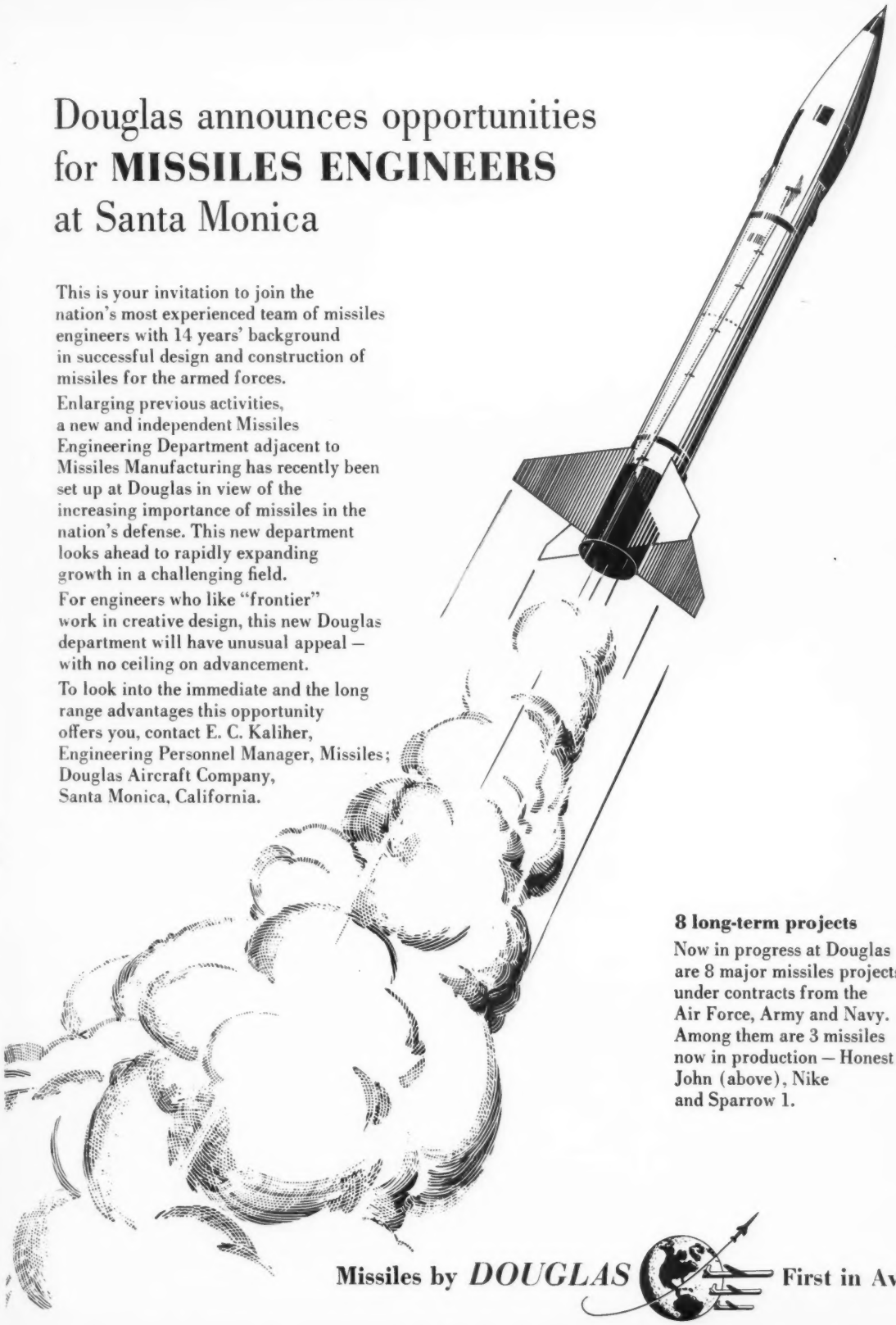

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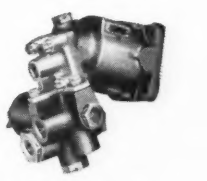

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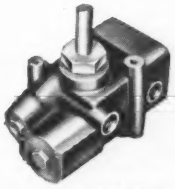

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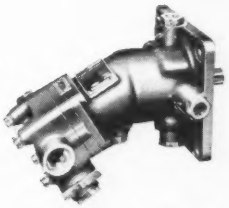

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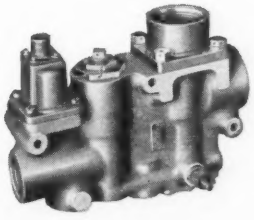

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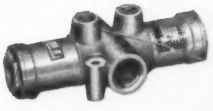

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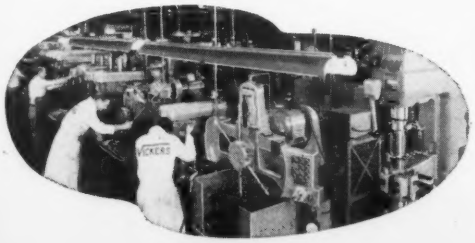

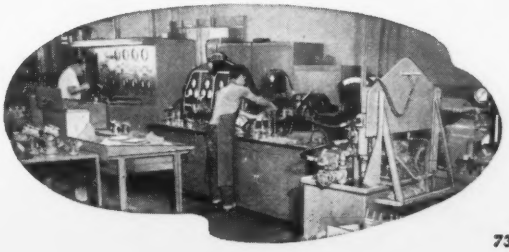

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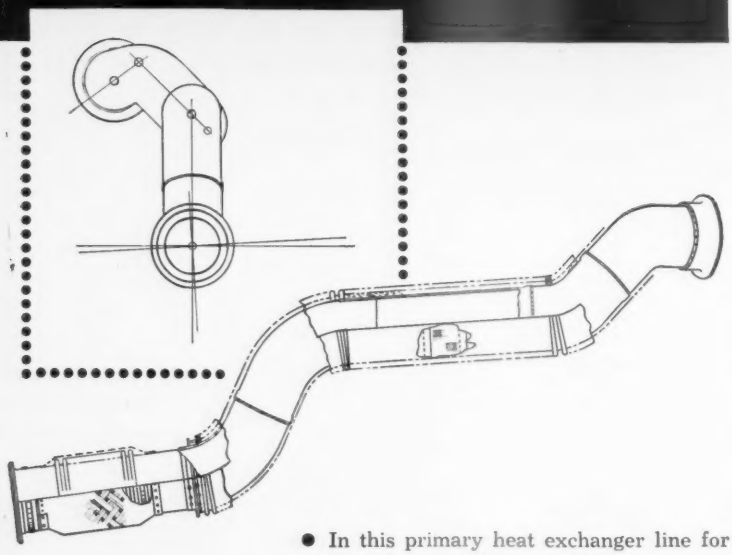

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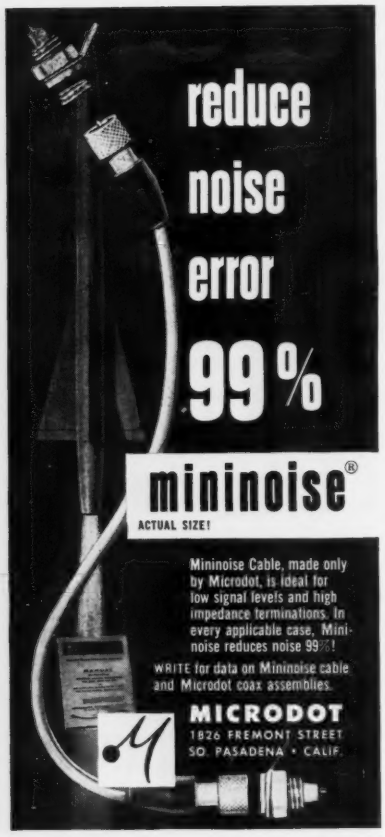
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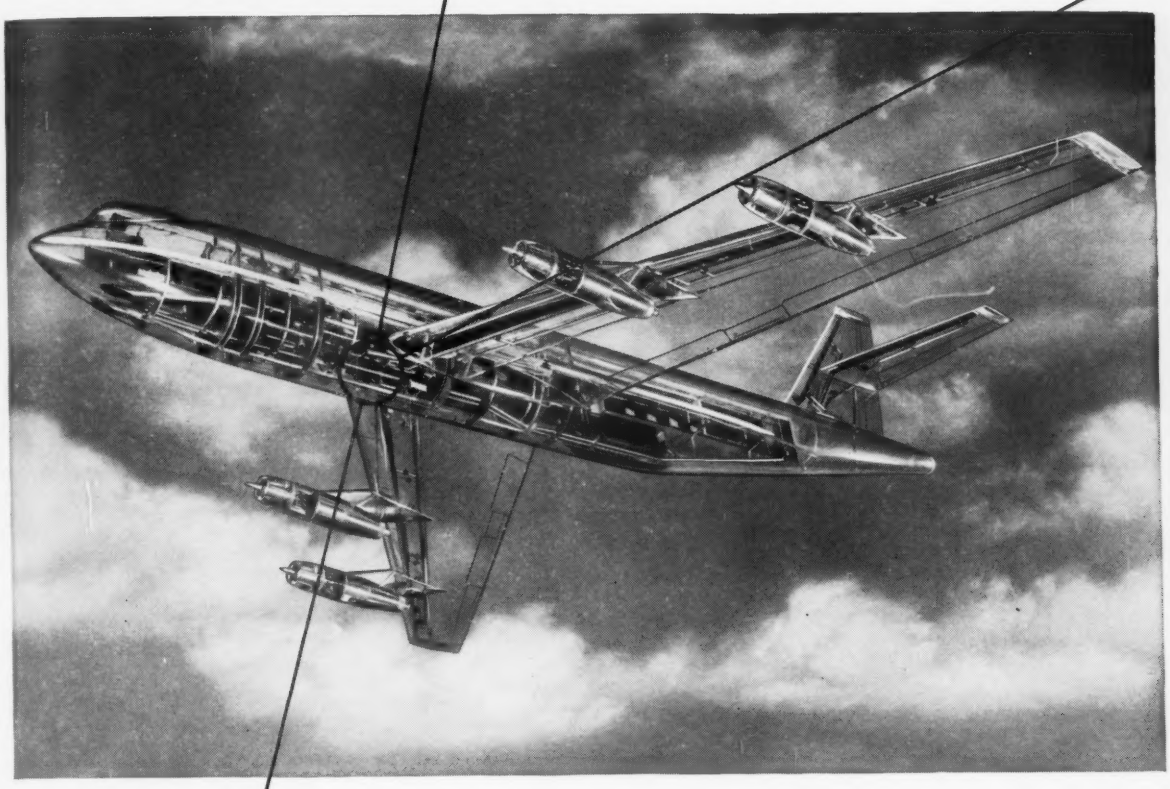

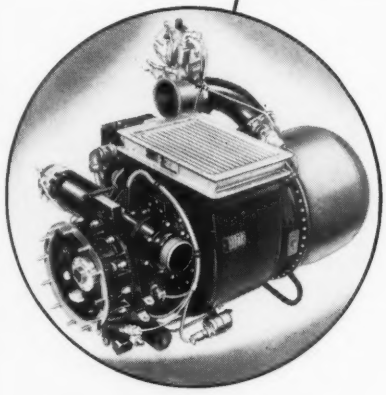

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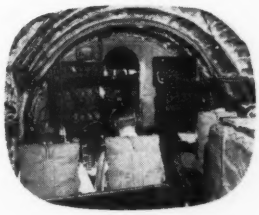

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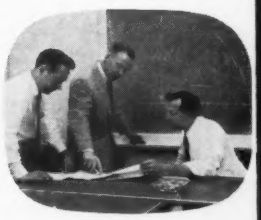

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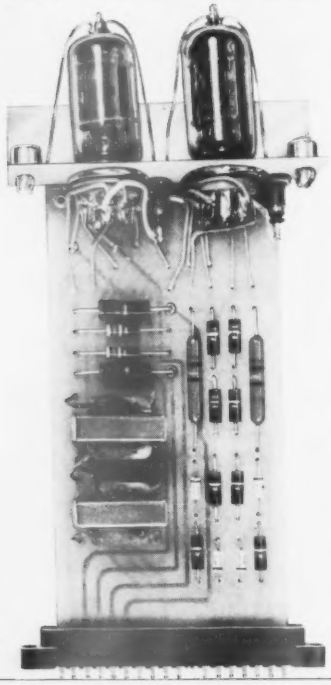

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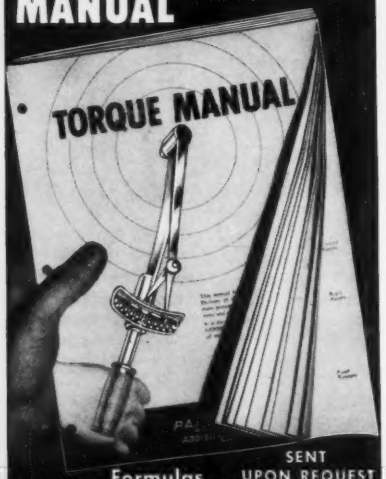

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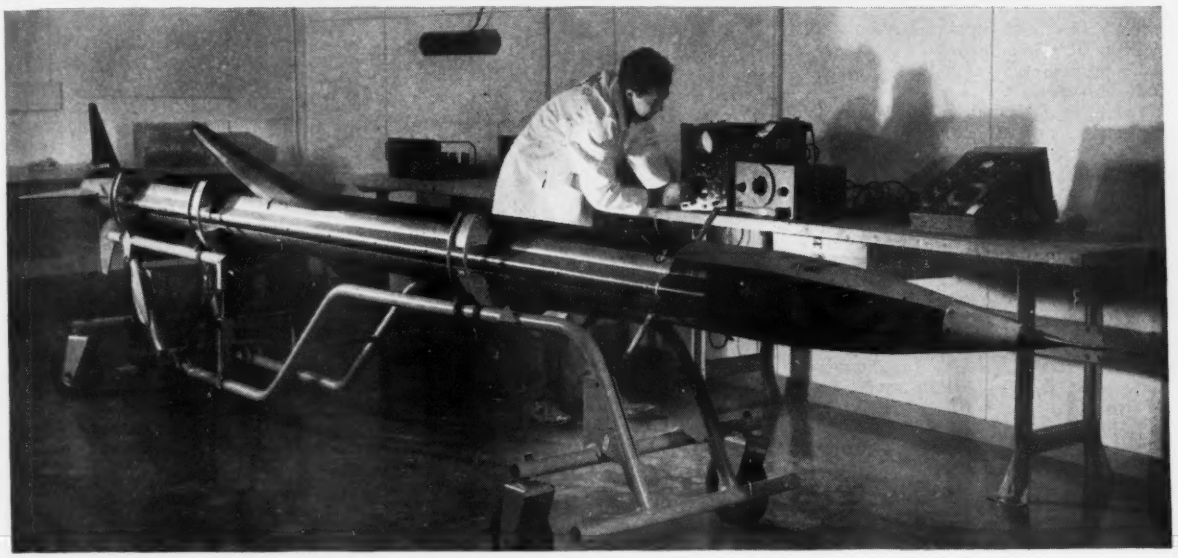

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Connections

Correlated Fatigue Data for Aircraft Structural Joints. R. B. Heywood. *Gt. Brit., RAE Rep. Struc. 184*, June, 1955. 16 pp. Test results on extruded, rolled, or forged aluminum alloy members, with a classification of modes of behavior and influencing factors including the method of design.

Cylinders & Shells

Comparison Between Theoretical and Experimental Stresses in Circular Semi-monocoque Cylinders with Rectangular Cutouts. Harvey G. McComb, Jr., and Emmet F. Low, Jr. *U.S., NACA TN 3544*, Oct., 1955. 20 pp.

Three-Dimensional and Shell Theory Analysis of Axially-Symmetric Motions of

Cylinders. G. Herrmann and I. Mirsky. *Columbia U. Inst. Air Flight Struc. AF TN 1*, Apr., 1955. 32 pp. 21 refs.

Plates

Analysis of Stresses in the Plastic Range Around a Circular Hole in a Plate Subjected to Uniaxial Tension. Appendix A—Simplification of Modified Complementary Energy Expression. Appendix B—Evaluation of Two Line Integrals. Appendix C—Description of Numerical Minimization Procedure. Bernard Budiansky and Robert J. Vidensek. *U.S., NACA TN 3542*, Oct., 1955. 39 pp. 10 refs.

The Load Carrying Capacity of Initially Flat Circular Steel Plates Under Reversed Loading. R. M. Haythornthwaite and E. T. Onat. *J. Aero. Sci.*, Dec., 1955, pp. 867–869. 12 refs.

On the Complex Representation of the General Extensional and Flexural Problems of Thin Plates and Their Analogies. Yi-Yuan Yu. *J. Franklin Inst.*, Oct., 1955, pp. 269–282. Generalization of the Muschelisvili-Lechnitzky method to include the effect of the body force and the lateral load.

Optimum Design for Reinforced Circular Holes. E. H. Mansfield. *Gt. Brit., RAE Rep. Struc. 183*, June, 1955. 26 pp. Method to determine the distribution of reinforcing material for a sheet with the least stress concentrations in terms of acceptable weight limits.

A Unified Theory of Perfectly Plastic Plates. Appendix I—The Relative Importance of Flexural and Torsional Hinge Lines. Appendix II—Total Collapse of a Perfectly Plastic Plate. Appendix III—Effect of Middle Surface Forces. Appendix IV—Work Done in a Radial Hinge Field of Arbitrary Form. Appendix V—General Boundary Conditions. Appendix VI—Collapse of a Regular Polygonal Plate Under Uniformly Distributed Load. E. H. Mansfield. *Gt. Brit., RAE Rep. Struc. 170*, May, 1955. 53 pp.

Variation of Maximum Thermal Stress in Free Plates. P. J. Schneider. *J. Aero. Sci.*, Dec., 1955, pp. 872, 873.

Testing

Axial Displacement Dislocations for the Hollow Cone and the Hollow Sphere. J. N. Goodier and J. C. Wilhoit, Jr. *Quart. Appl. Math.*, Oct., 1955, pp. 263–269. ONR-sponsored investigation at Stanford U. applying the Saint-Venant and Michell torsion theories to obtain simple solutions.

Fatigue Tests and Aircraft Life Evaluation; On the Experimental Correlation of Service Endurance Tests with Fatigue Tests at Constant Stress Amplitude. Tibor Haas. *Aircraft Eng.*, Oct., 1955, pp. 334–337. 22 refs.

The Influence of Pre-Loading on the Fatigue Life of Aircraft Components and Structures. Appendix I—Fatigue Tests on D.T.D.546 B Aluminium Alloy Sheet Specimens. Appendix II—Fatigue Tests on Lugs. Appendix III—Fatigue Tests on Channel-Sectioned Parts. Appendix IV—Fatigue Tests on Transverse Hole Specimens. Appendix V—Fatigue Tests on Wing Joints. Appendix VI—Fatigue Tests on Meteor 4 Tailplanes. Appendix

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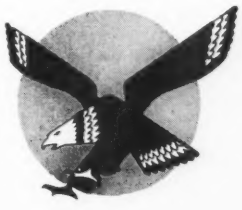

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VII—Fatigue Tests on (a) Circumferentially Notched Specimens, and (b) Spot Welded Joints. R. B. Heywood. *Gt. Brit., RAE Rep. Struc. 182*, June, 1955. 27 pp.

Investigation of the Fatigue of Extruded Tubular Booms. W. A. P. Fisher and H. Yeomans. *Gt. Brit., RAE TN Struc. 162*, June, 1955. 15 pp. Tests on Viking aluminum-alloy specimens.

Thermal Stress

Experiment and Theory in the Investigation of the Behavior of Structures at High Temperatures. N. J. Hoff. *CAI-IAS Internatl. Meeting, Ottawa, Nov. 3, 4, 1955, Preprint 572.* 15 pp. Members, $0.50; nonmembers, $0.85. Research at the Polytech. Inst. Bklyn into such problems of supersonic structural components as creep, thermal stresses, and bending.

Some Elevated Temperature Structural Problems of High-Speed Aircraft. Richard R. Heldenfels. *SAE Golden Anniv. Aero. Meeting, Los Angeles, Oct. 11–15, 1955, Preprint 599.* 19 pp.

Transient Temperature Distributions and Thermal Stresses in a Skin-Shear Web Configuration at High-Speed Flight for a Wide Range of Parameters. H. Schuh. (*KTH, Stockholm, Aero. Rep. FL 161*, 1954?) *J. Aero. Sci.*, Dec., 1955, pp. 829–836, 866. 10 refs.

Wings

Optimum Structural Design of Wing Box Beams. Saul Bernstein. *CAI-IAS Internatl. Meeting, Ottawa, Nov. 3–4, 1955, Preprint 569.* 19 pp. Members, $0.50; nonmembers, $0.85. Analysis of types of compression cover construction, including skin and Z-section stringers, double-skin corrugation panels, and solid-plate multiweb panels, taking into account applied bending moment per inch width of chord depth of the box beam and minimum skin thickness for torsional rigidity, with calculations of maximum compressive stress curves.

Thermodynamics

Liquid-Vapor Phase Equilibrium in Solutions of Oxygen and Nitrogen at Pressures Below One Atmosphere. George T. Armstrong, Jack M. Goldstein, and D. Ellis Roberts. *U.S., NBS Rep. 3921*, Jan. 31, 1955. 35 pp. 15 refs. USAF-sponsored investigation of fundamental properties of air and its component mixtures, with findings applicable to design problems of wind tunnels.

Surface Tension of Oxygen, Nitrogen, and Their Mixtures. M. L. Reilly and G. T. Furukawa. *U.S., NBS Rep. 3958*, Feb. 24, 1955. 39 pp. 22 refs. USAF-sponsored study of the properties of air and its components using the capillary rise method, with results applicable to wind-tunnel design.

Combustion

Burning Velocities of Various Premixed Turbulent Propane Flames on Open Burners. Paul Wagner. *U.S., NACA TN 3575*, Oct., 1955. 32 pp. 17 refs. Experimental measurements for systems of laminar velocities, densities, and viscosities.

Derivation of the Flame Equations, Their Transformation, and a Suggested Method of Their Solution. Appendix—Numerical Details Concerning the HBr Flame. G. Klein. *U. Wis. NRL Dept. Chem. Rep. SQUID-1*, Feb. 25, 1955. 91 pp. 10 refs.

Equations of a Simple Flame Solved by Successive Approximations to the Solution of an Integral Equation. V—A Simple Ideal Branching Chain Reaction Flame. Appendix—Numerical Application. G. Klein. *U. Wis. NRL Dept. Chem. Rep. SQUID-4*, Aug. 5, 1955. 40 pp.

Integration of a Simplified Kinetic Method for a Hydrogen-Bromine Flame. Appendix A—Possible Explanation for the Difficulty Met in the Previous Attempt to Integrate the Hydrogen-Bromine Flame Equations. Appendixes B—E. Appendix F—Values of Flame Variables Computed by the Implicit Six-Point Backward Difference Formula. Appendix G—Runge-Kutta Integration of the Diffusion Equations in the Neighborhood of the Cold Boundary. Appendix H—Integration of the Diffusion Equations in the Neighborhood of the Hot Boundary. Appendix I—Graphs of the Flame Variables and of the Major Reaction Rates. Appendix J—Use of the Eigen Value M in the Attempt to Fit the Cold Boundary Conditions for a Hydrogen-Bromine Flame. Edwin S. Campbell. *U. Wis. NRL Dept. Chem. Rep. CM-849*, July 18, 1955. 83 pp. 19 refs.

A Method for Integrating a Set of Ordinary Differential Equatons Subject to a Type of Numerical Indeterminancy. Appendix A. Appendix B—Values for the Power Series Coefficients; Values of Flame Variables and Their Derivatives Computed from Taylor Series Developments About t_0; Values Computed by Point by Point Numerical Integration; Graphs. Appendix C—Details of the Application of the Iterative Technique to the ABC Flame Equations; Runge-Kutta Integration of the Flame Equations; Formulae Used for the Integration with Backward Differences. Edwin S. Campbell. *U. Wis. NRL Dept. Chem. Rep. CM-847*, July 11, 1955. 56 pp. Application to basic combustion studies for a hypothetical free-radical flame.

Spark Ignition of Flowing Gases. V—Application of Fuel-Air Ratio and Initial Temperature Data to Ignition Theory. Appendix—Effect of Fuel Concentration on Ratio of Cathode Energy to Total Spark Energy. Clyde C. Swett, Jr. *U.S., NACA RM E55I16*, Nov. 1, 1955. 19 pp. 10 refs.

Heat Transfer

An Optimum Implicit Recurrence Formula for the Heat Conduction Equation. Stephen H. Crandall. *Quart. Appl. Math.*, Oct., 1955, pp. 318–320.

Water-Borne Aircraft

Hope for Rational Seaplane Design. John D. Pierson and Charles E. Carver, Jr. *Aero. Eng. Rev.*, Dec. 1955, pp. 26–30. 13 refs. Results of hydrodynamic analyses of such phenomena as waves, current, and meteorological influences on the sea surface applied to design problems.

Hydrofoil Craft: Present Status and the Central Problem. Frederick R. Furth. *SAE Golden Anniv. Aero. Meeting, Los Angeles, Oct. 11–15, 1955, Preprint 600.* 6 pp. ONR experimental investigations.

Investigation of High Length/Beam Ratio Seaplane Hulls with High Beam Loadings: Hydrodynamic Stability. I—Techniques and Presentation of Results of Model Tests. II—The Effect of Changes in the Mass, Moment of Inertia and Radius of Gyration on Longitudinal Stability Limits. VI—The Effect of Forebody Warp on Stability and Spray Characteristics. X—The Effect of Afterbody Length on Stability and Spray Characteristics. D. M. Ridland. *Gt. Brit., ARC CP 201, CP 202, CP 203, CP 204*, 1955. 50, 34, 34, 35 pp. 52 refs. BIS, New York. $1.25; 0.90; 0.90; 0.90.

Investigation of High Length/Beam Ratio Seaplane Hulls with High Beam Loadings: Hydrodynamic Stability. XXI—Some Notes on the Effect of Waves on Longitudinal Stability Characteristics. D. M. Ridland. *Gt. Brit., MAEE Rep. F/Res/257*, Aug. 1955. 58 pp. 33 refs.

Wind Tunnels & Research Facilities

Armstrong Whitworth Complete Mach 3 Variable Density Tunnel at Whitley. W. F. Hilton. *Hawker-Siddeley Rev.*, Sept., 1955, pp. 76–79.

The Flat Plate with an Angle of Attack in a Choked Wind Tunnel. K. Gottfried Guderley. *J. Aero. Sci.*, Dec., 1955, pp. 844–866. Extension of the Marschner investigation indicating the small wall influence on the pressure distribution over a wedge in transonic wind-tunnel testing, taking into account boundary conditions at the plate and at the walls.

Further Experiments with a Slotted-Wall Test Section. F. Vandrey. *Gt. Brit., ARC CP 207* (Mar. 4, 1953), 1955. 16 pp. Air and water tests on the problem of transition of a slotted-wall test section of a water tunnel to the diffuser.

Low Speed Wind Tunnel Calibration of a Mk.9A Pitot-Static Head. J. E. Nethaway. *Gt. Brit., RAE TN Aero. 2364*, Mar., 1955. 8 pp. Results indicating the variation of pitot and static pressure error coefficients with incidence at constant tunnel speed.

Aeronautical Reviews — BOOKS

AERODYNAMICS

Boundary Layer Theory. Hermann Schlichting. New York, McGraw-Hill Book Co., Inc., 1955. 535 pp., illus., diagrs. $15.

The work of Dr. Schlichting first came to widespread notice in this country in 1949 when NACA issued a translation of a course of lectures delivered by the author in 1941–1942. In 1951 Schlichting published an enlarged treatment of the subject in which much data previously under military security classification could be incorporated. This English edition, coming 4 years after its publication in German, benefits from new research and from the author's close collaboration with the translator, J. Kestin, a Professor at Brown University. Besides a number of minor revisions, two chapters—those on compressible boundary layers and on turbulent boundary layers with pressure gradients—have been completely rewritten. Dr. Hugh L. Dryden has written a foreword to the book.

Wave Diagrams for Nonsteady Flow in Ducts. George Rudinger. New York, D. Van Nostrand Company, Inc., 1955. 278 pp., diagrs. $6.00.

In the case of nonsteady flow through ducts, many specific problems must be solved by methods of graphical and numerical approximations, which are generally referred to as the method of characteristics. The resulting plots representing the propagation of waves in space and time are named wave diagrams. Because of the variety of computing procedures and the difficulties of obtaining the literature, the author has accumulated over the years a consistent set of procedures to cover most of the problems of nonsteady flow that ordinarily might be encountered. The text is so arranged that it can be used either as a convenient manual or for study by a newcomer to the field of unsteady flow. There are numerous illustrated examples and worked-out wave diagrams, in accordance with the emphasis on the practical aspects of carrying out the computations. The author is Principal Physicist, Cornell Aeronautical Laboratory, Inc. The test was prepared under the auspices of Project Squid which is sponsored jointly by the Office of Naval Research (Department of the Navy), the Office of Scientific Research (Department of the Air Force), and the Office of Ordnance Research (Department of the Army).

Contents: (I) Introduction. (II) List of Symbols. (III) Fundamentals of Wave Diagram Construction. (IV) The Wave Diagram. (V) General Flow Problems. (VI) Boundaries and Discontinuities. (VII) Interaction of Discontinuities. (VIII) Techniques of Wave Diagram Construction. (IX) Examples. (X) Bibliography. (XI) Charts and Tables. Appendix: Steady-Flow Relations. Index.

MATHEMATICS

Transactions of the Symposium on Computing, Mechanics, Statistics and Partial Differential Equations; Held at the University of Chicago, April 29-30, 1954. The Second Symposium on Applied Mathematics Sponsored by the American Mathematical Society and Office of Ordnance Research, U.S. Army. New York, Interscience Publishers, Inc., 1955. 216 pp., figs. $5.00.

Contents: Introduction. Operations Research, P. M. Morse. The Problem of Inductive Inference, Jerzy Neyman. Some Recent Developments in Analysis of Variance, H. O. Hartley. Two Unsolved Problems in Statistical Mechanics, J. E. Mayer. Iterative Computational Methods, M. R. Hestenes. Motivations for Working in Numerical Analysis, John Todd. Some Numerical Computations in Ordnance Problems, A. A. Bennett. The Simplest Rate Theory of Pure Elasticity, C. A. Truesdell. On the Stability of Mechanical Systems, J. J. Stoker. Divergent Integrals and Partial Differential Equations, Florent Bureau. On Differential Operators and Boundary Conditions, William Feller.

MECHANICS

Introduction to Theoretical Mechanics. Robert A. Becker. New York, McGraw-Hill Book Co., Inc., 1954. 420 pp., figs. $8.00.

In this text, designed for physics majors and first-year graduate students, emphasis is on the problem-solving point of view. Several applications to astronomy and atomic physics are presented in the form of problems, and many worked-out examples are included. Newtonian mechanics is emphasized in all but the last three chapters, since the author feels that this aspect of the subject must be completely mastered before the student is introduced to the short cuts provided by the generalized coordinate methods treated in the last three chapters. The preparation expected of the student is that obtained from thorough courses in elementary physics and calculus. Dr. Becker is Associate Professor of Physics, University of Illinois.

Contents: (1) Fundamental Principles. (2) Statics of a Particle. (3) Statics of Rigid Bodies. (4) Statics of the Suspended String or Cable. (5) Work and the Stability of Equilibrium. (6) Motion of a Particle in a Uniform Field. (7) Oscillatory Motion of a Particle in One Dimension. (8) Motion of a System of Particles. (9) Motion of a Rigid Body in a Plane. (10) Motion of a Particle Under the Action of a Central Force. (11) Accelerated Reference Systems and Constrained Motion of a Particle. (12) Motion of a Rigid Body in Three Dimensions. (13) Generalized Coordinates. (14) Vibrating Systems and Normal Coordinates. (15) Vibrating Strings and Wave Motion. Appendix 1, Area and Volume Elements in Common Coordinate Systems. Appendix 2, Elements of Ordinary Differential Equations. Appendix 3, Note on Hyperbolic Functions. Appendix 4, Commonly Employed Expressions Involving Partial Derivatives. Appendix 5, Note on Fourier Series. Index.

Engineering Mechanics. Archie E. Higdon and William B. Stiles. 2nd Ed. New York, Prentice-Hall, Inc., 1955. 585 pp., illus., diagrs. $7.95.

This is the second edition of a textbook designed for use through two successive terms. It emphasizes the understanding of principles and the correct analysis of problems by application of principles. In this revised edition, three chapters have been reorganized, the problems extensively revised, and numerous other changes made. Colonel Higdon is acting Head of the Department of Mathematics, U.S. Air Force Academy, and Professor Stiles is Head of the Department of Engineering Mechanics, University of Alabama.

POWER PLANTS

Cycles and Performance Estimation. James Hodge. (Gas Turbine Series, Volume 1.) London, Butterworths Scientific Publications; New York, Academic Press Inc., 1955. 329 pp., diagrs. $9.00.

This is the first volume in a series to be edited by Mr. Hodge in collaboration with others on the Consulting Staff of Power Jets (Research and Development) Ltd. The author, whose experience with gas turbines dates from the early years of World War II, was Visiting Professor of Mechanical Engineering at Columbia University between 1953 and 1954. The present volume lays down the basic principles by which the performance of a gas turbine can be assessed.

Contents: (1) Scope and Objects, Definitions, Basic Data, Methods of Cycle Calculation. (2) Formal Theoretical Analysis of Some Idealized Cycles—Shaft Power and Jet Energy-Producing Types. (3) Performance of Cycles Generating Shaft Power Only. (4) Performance of Aircraft Engine Cycles. (5) Some Examples of Other Applications of Gas Turbine Type Plant. (6) The Estimation of Performance of Gas Turbines Operating Away from the Design Point. Index.

Gas Turbines and Jet Propulsion. G. Geoffrey Smith. 6th Ed. London, Iliffe & Sons, Ltd.; New York, Philosophical Library, 1955. 412 pp., illus., diagrs. $15.

This book has been generally recognized as a standard work since it was first published in 1942. With the death of the author in 1951, the work of revising the fifth edition was taken up by F. C. Sheffield, who was closely associated with Smith in the earlier revisions of the book. This sixth edition has been completely reset in a new format which retains, for the most part, the original drawings and diagrams.

PRODUCTION

SAE Production Forum on Aircraft; Discussions at the Aircraft Production Forum at Los Angeles, October 5, 6, 1954. New York, Society of Automotive Engineers, Inc., 1954. 160 pp., illus., diagrs. $2.00.

Comprises panel discussions on the following topics: Tabulating-in-Industry. Electronics.

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RESEARCH

Proceedings of the Symposium on Operations Research in Business and Industry. Sponsored by Midwest Research Institute, April 8 and 9, 1954. Kansas City, Mo., Midwest Research Institute, 1954. 185 pp., figs. $5.00.

Contents: History and Prospects for Operations Research, C. West Churchman. Operations Applied to the Office, Earl Lamm. Operations Research—A Boon to Marketing, J. H. Davidson. A Discussion of the Major Tools of Operations Research, Edward C. Varnum. Production and Inventory Control in a Chemical Process, Russell L. Ackoff. Computational Experience in Solving Linear Programming Problems, Wm. Orchard-Hays. Problems of Traffic and Transportation, William Prager. Balancing Cost and Quality in a Department to Provide Lower Over-All Manufacturing Costs, Sherman Kingsbury. Experimentalism, Statistical Control and Cybernetics in Industrial Management, Sebastian B. Littauer. Operations Engineering, Planning and Research, J. E. Garrett. Scheduling of Batched Operations in Petroleum Products Pipe Lines, Tage A. Mortensen. Panel Discussion. Summary and Closing Remarks, J. W. Allen. List of Participants.

ROTATING WING AIRCRAFT

Rotorcraft. R. N. Liptrot and J. D. Woods. London, Butterworths Scientific Publications, 1955. 172 pp., illus., diagrs. 32s.

This book is an introduction to the theory and practice of rotary-wing aircraft, explaining the fundamentals of rotorcraft engineering in a simple and practical manner. It is also a handy compilation of available data on past and present types of rotorcraft and contains an extensive bibliography on the subject.

Proceedings of the Second Annual Forum, September 21 and 22, 1955, Los Angeles. New York, American Helicopter Society, Inc., September, 1955. 171 pp., illus. $5.50; $3.50 to AHS Members.

Contents: Design Session: Some Stability Problems of Vertically Rising Aircraft, Charles H. Zimmerman. Performance Requirements for Transport Rotorcraft, R. L. Lichten. Structural Design of a Rotor Blade Having a Spanwise Discontinuity, Ellis B. Kuhns.

Development Session: A Simplified Approach to the Aerodynamic Rotor Interference of Tandem Helicopters, W. Z. Stepniewski. Development of Airborne Personnel Platform, Arthur C. Robertson. Development and Service Testing of the 47J Helicopter, J. Robert Duppstadt.

Operations Session: Cost of Operation and Maintenance of Army Aircraft, H. P. Crane. Helicopter Instrumentation, George W. Hoover. Anti-Submarine Warfare Helicopter Work, C. S. Tanner.

Power Plant Session: Power Plants for the Army, D. D. Weidhuner. Helicopter Power Plant Current Requirements and Developments, R. R. Thoe. Helicopter Power Plants, Leroy A. Howard. Geared Gas Turbines for Helicopters, D. C. Berkey. Special Power Plants, H. H. Ostroff. Why the Lack of Small, Light-Weight Aircraft Engines, Robert David.

Special Types of Rotary Wing Aircraft. Eugene K. Liberatore. (Rotary Wing Aircraft Handbooks and History; Eugene K. Liberatore, Editor, Vol. 11.) Prepared for WADC, ARDC, Wright-Patterson AFB, Ohio. Washington, Office of Technical Services, 1954. 131 pp., illus. $3.50; PB 111633.

This volume contains an account of over 200 miscellaneous types of aircraft that may be included under the heading of rotary wing aircraft. The volume is divided into parts which deal with cyclogiros, magnus effect rotorcraft, ornithopters, and other miscellaneous types. In each part the information is given in alpha-

betical order according to the name of the company or designer.

SERVOMECHANISMS

Elements of Servomechanism Theory. George J. Thaler. New York, McGraw-Hill Book Co., Inc., 1955. 282 pp., diagrs., figs. $7.50.

The elements of feedback control theory and the normal modern methods of applying them are presented in such a way as to make the material teachable at the undergraduate level. Higher mathematics has not been used, and, in order to provide adequate practice in modern techniques, the polar and logarithmic approaches are handled simultaneously. The book covers loop systems and offers sufficient material on multiloop systems to introduce the problems involved and the basic approaches to solutions. The two final chapters introduce briefly advanced topics such as root locus methods, phase plane techniques, and describing functions. Several important departures in presentation of the material may be noted. System equations and transfer functions are handled by circuit theory rather than the Laplace transformation. An ample supply of problems is included. The material has been tested in the classroom over a 3-year period by the author, who is Associate Professor of Electrical Engineering, U.S. Naval Postgraduate School.

Contents: (1) Introduction. (2) General Aspects of Analysis and Design. (3) Transient Analysis of Servomechanisms. (4) Transfer Functions. (5) Transfer-Function Plots. (6) Analysis of Single-Loop Systems. (7) Methods of Meeting Performance Specifications. (8) Gain Adjustment of Servomechanisms. (9) Series Compensation of Servomechanisms. (10) Feedback Compensation of Servomechanisms. (11) Introduction to Advanced Topics—Linear Theory. (12) Introduction to Advanced Topics—Nonlinear System. Appendixes. Index.

SPACE TRAVEL

Space-Flight Problems; Being a Complete Collection of All Lectures Held at the 4th Astronautical Congress, Zurich, 1953. Published by the Swiss Astronautical Society for the International Astronautical Federation. Biel, Switzerland, Laubscher & Cie., 1954. 224 pp., illus., diagrs.

Contents: The International Astronautical Federation. Eröffnungsansprache (Opening Remarks), J. Ackeret. Zur Thermo-dynamik von Arbeitsgasen für Atomraketen. (The Thermodynamics of the Working Gases of Atomic Rockets), Irene Sänger-Bredt. Zur Theorie der Photonenraketen (The Theory of Photon Rockets), Eugen Sänger. Zum Problem der Kühlung von Atomraketen bei Verwendung thermonuklearer Reaktionen (The Problem of Cooling Atomic Rockets Utilizing Thermonuclear Reactions), H. J. Kaeppler. Margin for Error, Milton W. Rosen and Richard B. Snodgrass. Earth Scanning Techniques for a Small Orbital Rocket Vehicle, Kurt R. Stehling. The Application of Radio Interferometry to the Guidance of Interplanetary Rockets, Marcel J. E. Golay. Ueber ringförmige Tragflügel (Ring Airfoils), Z. Plaskowski. Strahl-umlenkung für Bremszwecke (Jet Reversal for Braking Purposes), K. Iserland. La pésee des forces aérodynamiques sur un corps de révolution et la calcul élémentaire de la composante normale (The Balance of Aerodynamic Forces on a Body of Revolution and the Elementary Calculation of the Normal Component), H. R. Voellmy. Die Bahnbestimmung aus dem Vektor der Eigengeschwindigkeit und der Einfluss einer Aenderung derselben auf die Bahnelemente (The Determination of Trajectory from the Vector of the Trajectory Velocity and the Influence of a Change in Trajectory Velocity on the Trajectory Elements), K. Schütte. A General Formula for the Relation between a Field of Forces and the Orbit of a Body Therein, A. Lopez Cardozo. On Plotting Small Thrust Space Ship Orbits, J. M. J. Kooy. The Spherical Differential Analyzer for Solving Differential

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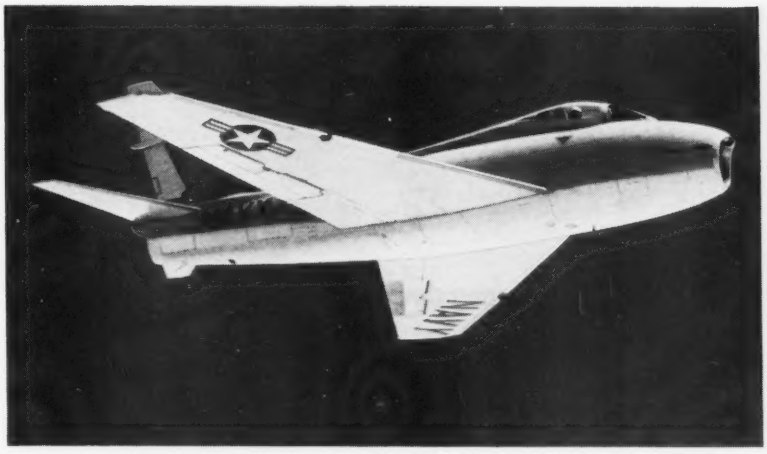

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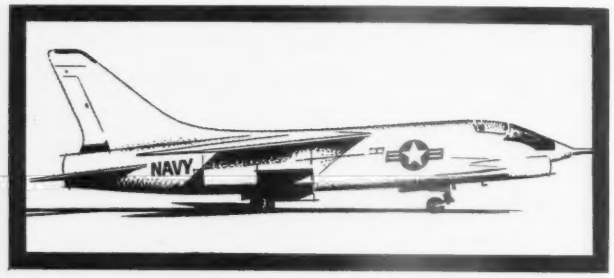
Equations Arising in Space Travel Problems, M. J. Bottema. Fabrication of the Orbital Vehicle, A. E. Dixon, K. W. Gatland, and A. M. Kunesch. A Minimum Orbital Instrumented Satellite—Now, S. F. Singer. Some Limiting Factors of Chemical Rocket Motors, W. N. Neat. La ravitaillement dans l'espace et le problème des polistades (Refueling in Space and the Problem of Multistage Vehicles), G. A. Crocco. Die Erniedrigung des Erstarrungspunktes (The Lowering of Fuel Freezing Point), R. M. Corelli. Materials for Rocket Frame and Motor Construction, G. P. Casiraghi. Strenge Integration der Bewegungsgleichung einer senkrecht aufsteigenden Rakete nach Brennschluss in der Erdatmosphäre (Rigorous Integration of the Equation of Motion of a Vertically Ascending Rocket after Burn-Out within the Earth's Atmosphere), H. G. L. Krause. Zum Problem der rationellen thermoelektrischen Stromerzeugung im extraterrestrischen Aufgabenbereich (The Generation of Electric Current by Thermoelectric Means—An Extraterrestrial Problem), B. Langenecker. Zur Frage der Orientierung im schwerefreien Zustand (The Problem of Orientation in the Gravity-Free State), S. Gerathewohl. Untersuchungen über Schwerelosigkeit an Versuchspersonen und Tieren während des lotrechten Sturzfluges (Investigations on Weightlessness on Research Personnel and Animals during Vertical Flight), H. J. A. von Beckh. Zur Untersuchungstechnik der Erforschung der biologishen Wirkung der kosmischen Strahlung in grossen Höhen (Technique of Conducting Research on the Biological Effect of Cosmic Radiation at High Altitudes), J. Eugster. We Need a Coordinated Space Program, Wernher von Brown. We Can Have Space Flight in Our Time, R. C. Truax. Co-Operation among Rocket Societies in the Present State of Astronautical Research, G. Partel. Zur Psychologie der volkstümlichen Vorträge über Raumflüge (The Psychology of Popular Lectures on Space Flight), E. Dolezal. Programme d'Action, Crocco.

TECHNICAL INFORMATION

Information Processing Equipment. M. P. Doss, Editor. New York, Reinhold Publishing Corp., 1955. 270 pp., illus., figs. $8.75.

Equipment used in the preparation, reproduction, and utilization of written information are described and illustrated in this useful book. The idea for the book was conceived as a result of the Symposium on this subject sponsored by the Division of Chemical Literature of the American Chemical Society. The Editor is the 1955 Chairman of this Division, and for over 30 years he has been Technical Librarian of the Research and Technical Department of the Texas Company. The bibliographies given at the ends of chapters are extensive.

Contents: (1) Special Typing, Stenciling, Hectographing, Figure Preparation, and Miscellaneous Equipment, Robert E. Mixson. (2) Lensless Copying with Sensitized Papers, Frank E. Smith. (3) Photography in the Laboratory, L. C. Stork and M. P. Doss. (4) Microcopying, Methods and Use, Hubbard W. Ballou. (5) Xerography: Dry Photographic Copying, B. H. Weil. (6) Letterpress and Offset Printing, George G. Taylor. (7) Author's Guide to Effective Slides—Projection Equipment and Copy Preparation, L. S. Bonnell, C. R. Paul, Jr., and I. S. Rice, Jr. (8) Audio Methods for Handling Data, R. C. McMaster, Benjamin L. Schwartz, and Patricia S. Jenkins. (9) Storing and Finding Technical Information with Punched Cards, Charles A. Burkhard. (10) Numerical Data-Handling Machines, J. J. Stone and A. T. Maierson. Index.



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This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Stress Analysts and Structures Engineers—Growing engineering research and development organization needs men with 1–5 years' experience preferably in thermal and stress analysis, aircraft or missile structural work. Apply Personnel Department, Aerophysics Development Corporation (subsidiary of Studebaker-Packard), Box 949, Santa Monica, Calif.

Aeronautical Engineers—The National Advisory Committee for Aeronautics is offering varied employment opportunities in many fields of aeronautical research for both recent graduates and experienced engineers. Aeronautical Engineers are required for research in problem areas such as the following: Supersonic aerodynamics, boundary-layer and heat-transfer studies, viscous flow and separation, blading and cascades, mixed flow, compressor surge, turbine cooling, matching of compressors turbines. Application of combustion fundaments to design of combustors to operate beyond current limits; fuel injection and turbulence mixing. Aerodynamic instruments for basic measurements in high-velocity compressible gas streams, hot-wire anemometry; electronic analog computers for theoretical studies. Full-scale engine research to study rotating stall, altitude blowout; turboprop, turbojet, and ram-jet performance at high speeds and extreme altitudes; inlet flow distortion, thrust augmentation, jet-ejectors, thrust reversal, screech suppression; special cycles of turbo-gas-generator with tip-burning pressure jets for rotorcraft; vertical take-off aircraft; power-plant installation; operational limitations and control problems for ram-jet, turbojet, and turboprop engines. Nuclear reactor analysis for aircraft propulsion; heat-transfer rates and media; cycle analysis for nuclear engine. These positions offer challenging assignments, a professional atmosphere among experts, and recognition on a national and even international level. Excellent opportunities for creative research. Salaries are commensurate with qualifications and assignments. Advanced study is encouraged and may be pursued while in full-pay status. Ample leave and other fringe benefits are provided. Further information may be obtained by writing: NACA, Lewis Flight Propulsion Laboratory, Room 350, ASB, 21000 Brookpark Road, Cleveland 11, Ohio.

Associate Professor or Professor—Staff opening available for appointment beginning March 15 or September 1, 1956. Applicant should be qualified to teach undergraduate and graduate courses in aerodynamics, also to direct and carry out research. Enclose an outline of education, experience, and references in initial reply. Ph.D. degree desirable. Send replies to: Professor E. W. Anderson, Head, Department of Aeronautical Engineering, Iowa State College, Ames, Iowa.

Aeronautical Engineer—Individual with B.S. degree in Aeronautical Engineering and 1–3 years in applied aerodynamics. He will be doing calculations on stability and control, classic and power-plant performance. Should be capable of reducing aerodynamic data to equation form suitable for electronic simulation. Good opportunities for advancement. Excellent employee benefits and suitable housing available. Send résumé to: W. W. Wood, Vice-President, Engineering, Link Aviation, Inc., Binghamton, N.Y.

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Engineers—The following vacancies exist at the Special Devices Center, Port Washington, N.Y. **Aeronautical Engineer**—$4,345 per annum (Requirement: B.A.E. degree). **Aeronautical Engineer**—$4,930 per annum (Requirement: B.A.E. degree plus 6 months' professional research and development experience). **Aeronautical Engineer**—$5,440 per annum (Requirement: B.A.E. degree plus 1½ years' professional research and development experience). **Aeronautical Engineer**—$6,390 per annum (Requirement: B.A.E. degree plus 2½ years' professional research and development experience). Inquiries should be addressed to the Commanding Officer and Director (Attention: Industrial Relations Officer), Office of Naval Research, Special Devices Center, Port Washington, Long Island, N.Y. Telephones: FLushing 7-8300 or Port Washington 7-3800.

Engineers — Aeronautical Engineers — The Navy Department, Bureau of Aeronautics, has a number of positions available in the following fields of aeronautical engineering including research and development: structural loads, vibration and flutter, aerodynamic heating, cruise control, performance, and related mechanical, electrical, and electronic components. Salaries for most positions are at the GS-11, $6,390 per annum and GS-12, $7,570 per annum levels. Positions require 2½ or 3½ years of experience. Applications, Standard Form 57 (available at most Government offices) should be sent to: Bureau of Aeronautics, Personnel Division (PE-202), Main Navy Building, Washington 25, D.C. **Aeronautical Development Engineer**—This position is also available with the Bureau of Aeronautics at the GS-14 salary level, $10,320 to $11,395 per annum. The incumbent will be responsible for directing the work of a branch which will include the following functions: (a) planning and administering research and development programs related to special weapons effects, (b) coordinating Bureau of Aeronautics participation in atomic weapon tests, (c) developing design criteria and establishing specification requirements to ensure suitability of new aircraft for delivery of special weapons, and (d) preparation and promulgation of weapon effects handbook material to the fleet. Required qualifications include a comprehensive background in aircraft structures and aerodynamics, some knowledge of operational tacts and nuclear blast effects, and the ability to design test programs. Applications should be sent to the above address

Associate Professor or Professor—The School of Engineering of the University of Wichita has a vacancy in the rank of Professor or Associate Professor of Aeronautical Engineering to instruct senior and graduate courses in the fields of stress analysis and structural dynamics. If desired, an abbreviated teaching load may be combined with research conducted in the Department of Engineering Research. Appointment will be for 11 months each year with a salary dependent on experience. Applicant should have Ph.D. degree. Apply: Head, Department of Aeronautical Engineering, University of Wichita, Wichita, Kansas.

Engineers—Princeton University, Department of Aeronautical Engineering, Jet Propulsion Research Program has positions available for qualified engineers, as described below, for work on basic and engineering researches in the field of jet propulsion. These are key positions in the Jet Propulsion Research Program of the Department of Aeronautical Engineering, located at the James Forrestal Research Center. Opportunity is provided for responsible research in jet propulsion and associated sciences. These positions are academic appointments with corresponding university privileges, including 1 month's annual vacation, participation in graduate course work, and other benefits. **Senior Research Engineer**—Recent Ph.D. in any of the sciences relating to combustion or M.S. with several years' experience to serve as engineer in charge of research projects. **Instrumentation Engineer**—M.S. with several years' experience or equivalent to head staff instrumenting group. **Junior Research Engineer**—Research-minded M.S or B.S. with experience in rocket system technology and/or propellant evaluation and background in chemistry to serve as assistant engineer in charge of a research project. Please send résumé or request for further information to: Mr. J. P. Layton, Chief Jet Propulsion Research Engineer, Department of Aeronautical Engineering, James Forrestal Research Center, Princeton University, Princeton, N.J.

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